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Energy, Mines and Resources Canada
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NUCLEAR INDUSTRY REVIEW

Problems and Prospects 1981-2000

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Canada

NUCLEAR INDUSTRY REVIEW

Erratum: Figure 3, page 20, footnote should read:

"includes 15% reserve ratio. Utility forecast curve taken from earlier study; if based on most recent 4.7% per annum load growth the utility forecast would rise to approximately 55 000 MWe in the year 2000."

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1. OVERVIEW

The nuclear industry, like many other industries, is subject to significant fluctuations in demand. As late as 1974/75 there was real concern that the Canadian industry would be unable to satisfy domestic requirements and fill export orders simultaneously. Projections indicated that up to 130 000 MWe of nuclear capacity would be operating in Canada by 2000. This would have required construction of about four reactors per year for the rest of the century, while export orders might have added another reactor unit per year. The industry, however, had a production capacity of only about three reactor units per year, and heavy water was in short supply even in relation to domestic requirements.

Today the picture is very different. Nuclear power faces problems in Canada and around the world. Slowdowns in economic growth have meant that ambitious programs for the expansion of nuclear generating capacity have had to be deferred. In some countries, nuclear units already on order have been cancelled. This has led to problems of excess capacity in the domestic nuclear industries of most of the nuclear supplier countries, with the exception of France and perhaps the Soviet Union. Future export prospects for nuclear reactors have also declined from previous projections. In the few importing countries where there are dynamic nuclear programs, such as Korea, Mexico, and Taiwan, there is intense competition among suppliers seeking to compensate for their reduced domestic markets.

The basic purpose of this review is to examine the consequences of projected excess capacity for the maintenance of an independent nuclear power capability in Canada. It will examine the possibility that commercial problems may slow or arrest technological progress, allow highly skilled labour and specialized capital to be diverted to other uses, and thus affect not only the cost and reliability but also the availability of the CANDU* option. The major question addressed is whether as a result of decreases in demand, both at home and abroad, the Canadian industry may not have enough reactor orders in the shops now to sustain it beyond the middle of the decade. If new orders are not forthcoming in the next few years, the CANDU option may be lost.

Canada has a strong commitment to nuclear power. Eight large CANDU units are operating very successfully in Ontario, and twelve more units are under construction there. Six CANDU units are under construction elsewhere, two in Romania, and one each in New Brunswick, Quebec, Argentina and Korea. These latter four will be in service in 1982 or 1983. Canada's commitment to supporting and enhancing the performance of these reactors will be maintained. The term ''losing the industry'' or ''losing the CANDU option'' is used in this report to indicate the possibility that the ability of Canada's nuclear industry to respond competitively to *new* orders for reactors will be lost. It does not mean that Canada would lose the ability to support and maintain those reactors now in operation or under construction.

The future of nuclear power in Canada and abroad is further clouded by non-economic factors, the most important of which are problems of public acceptability. In the domestic market, major public concerns focus on the impact of nuclear energy on public health and the natural environment, and on the safety of reactor operations. The long term management of radioactive wastes is perceived to be a particularly difficult problem. With respect to foreign sales, public concern has focussed on the potential contribution of CANDU exports to the proliferation of nuclear weapons and, to a lesser extent, on financial losses associated with foreign contracts.

On balance, the view of the government has been that the problems posed by nuclear technology are manageable, and that the benefits of both the domestic and export programs outweigh the risks. In fact, the nuclear power program in Canada was initiated by the federal government which has supported the industry on a continuing basis for three decades. A number of initiatives have been undertaken to address specific issues of public and technical concern. On the domestic side, a vigorous

*CANDU is an acronym designating the Canada-Deuterium-Uranium reactor system.

program has been designed to ensure that the concept of deep burial in stable rock formations will be an effective method for the permanent disposal of high level radioactive wastes. It is expected that this concept will be shown to be fully acceptable by the end of the decade. In the meantime, storage of spent fuel at reactor sites is proving to be a cheap, safe, and reliable method which can be continued for 30 or 40 years without problems. Numerous commissions and inquiries, the most recent being the Ontario Select Committee on Ontario Hydro Affairs, have determined that CANDU is acceptably safe. With respect to exports, reactors are offered for peaceful purposes only to those countries willing to accept Canadian safeguard policies. These policies were tightened in the mid-1970's to the point where the conditions required by Canada are among the most stringent of any nuclear exporter. These conditions have been fully accepted in bilateral agreements by all but a very few of the countries with which Canada wishes to have nuclear cooperation agreements.

New evidence on environmental, safety or proliferation concerns could lead to a re-evaluation of the government's position at any time. However, this paper leaves aside consideration of the global problems* associated with nuclear energy and focuses on the narrower but nevertheless important question of the potential commercial problems facing the industry over the next decade or so.

The central thesis of this paper is that domestic demand for electricity may require new CANDU units to come on stream in the mid-to-late 1990's. This reflects the reality that non-nuclear alternatives for meeting load growth requirements are limited to coal and hydro, both of which are becoming increasingly costly in economic and environmental terms, especially east of Manitoba. At the same time increased export opportunities for the CANDU may also come to fruition later in this decade. While it is unlikely that domestic and export demand for reactors will be sufficient to sustain the industry in its current form on an on-going basis, it is likely that demand will be adequate to employ fully a rationalized industry. In this context, it may be sensible to take steps to ensure that an indigenous nuclear option based on the CANDU fuel cycle will be available at that time; or more conservatively, to take those steps required to ensure the industry's viability until such time as the domestic demand for nuclear energy in the 1990's can at least be determined with more certainty.

This review is not to consider support of the industry for its own sake. Rather, the issue is whether the government should attempt to sustain the industry through several years of slack demand, given that it may be needed at the end of that period. The real issue is one of timing: is the period of slack demand short enough to justify governmental efforts to maintain the nuclear industry? If the CANDU were seen to be needed in 30 years, but not before, it would hardly be sensible to maintain a complete industrial capability through the intervening decades.

In sum, the outlook for the industry is uncertain. On the one hand, there is some possibility that enough orders will be placed over the next few years to sustain the industry, even without government intervention. On the other hand, even with strong government support further sales may not be forthcoming in the short term. This review therefore seeks to establish whether, with or without action, a Canadian nuclear supply capability will continue into the 1990's to meet electrical demands expected at that time, and to identify the problems and opportunities the industry faces.

Briefly, the analysis in the report indicates that, based on the clear economic advantages of CANDU in generating electricity to meet domestic load growth (particularly east of Manitoba) orders will likely be placed in the latter part of the 1980's for domestic reactors to come on stream in the 1990's. Second, some reactor export markets appear promising and, given Canada's improved aggressive marketing approach, some optimism about future prospects is warranted. Finally, there appear to be attractive opportunities to prebuild nuclear reactors in Canada to export electricity to U.S. markets. Together, these markets should support a rationalized Canadian nuclear industry from the late 1980's on. In the meantime, the report concludes government support may be required. Such support is

*These issues are addressed in the Nuclear Policy Review Background Papers released by the Minister of Energy, Mines and Resources on August 4, 1981.

justified by the long term economic, industrial and technological benefits associated with an indigenous Canadian nuclear technology.

The review was begun in 1980, and much of the background work was done in the summer and fall of that year. The review went through several drafts as a discussion paper in the summer of 1981. This version dates from the fall of 1981. Important developments since then have been incorporated to the extent possible.

2. DESCRIPTION OF THE REACTOR AND HEAVY WATER SUPPLY INDUSTRIES

Historical Background

The origins of the heavy water moderated reactor can be traced back to France and Norway in 1939. With the outbreak of the war, a joint Canadian-British laboratory was established in Montréal and fundamental research was carried out independent of work in the U.S. On September 5, 1945, the first nuclear reactor outside of the U.S. "went critical" in Canada. After the war, Canada turned its attention to the development of nuclear electricity generation.

In 1954, the federal government, through Atomic Energy of Canada Ltd. (AECL), and the Ontario Government, through Ontario Hydro, jointly undertook the feasibility studies which were the first step in developing the CANDU power reactor system. Representatives of five Canadian utilities as well as private industry and consultants participated in these studies. Because of wartime Canadian experience with heavy water natural uranium systems, and because of the desire to avoid dependence on foreign sources of enrichment as well as its attractive technological and engineering features the heavy water/natural uranium design was chosen as a basis for the development of commercial power reactors. Since then, the evolution and development of CANDU has produced a technology which is particularly suited to Canada's industrial structure, resource base, and accumulated expertise.

The CANDU reactor design which emerged has several technological and economic advantages. First, the use of heavy water as a moderator and coolant, combined with a design which maximizes efficiency, allows the reactor to be fuelled with natural uranium; consequently, the efficiency with which uranium is converted to useable energy is high. Second, the use of pressure tubes, rather than a single large pressure vessel, as in light water reactors (LWRs), facilitates fuelling of the reactor while in operation, increasing plant availability. Third, the pressure tube design is relatively easy to adapt to countries with less developed industrial structures. Finally, while making efficient use of natural uranium on a once-through basis, the CANDU fuel cycle can be modified fairly simply to embrace advanced fuel cycles, extending the useable energy obtainable from uranium resources (and eventually, thorium).

Since 1954, CANDU has been rapidly developed and deployed commercially in Canada (see Table 1). By 1980, CANDU reactors generated about 38 per cent of the electricity consumed in Ontario, valued at some $1 billion. Its success is based on a number of technical and economic factors. First, CANDU provides a complete and largely autonomous nuclear fuel cycle for generating electricity which makes use of Canadian resources and Canadian technology. Second, it is economically competitive with coal-fired generation in large parts of the country, especially east of Manitoba. Technical performance has been outstanding; in lifetime gross capacity factors, seven of the world's

TABLE 1
CANADA'S DOMESTIC NUCLEAR POWER PROGRAM

Reactor or Station	Capacity, MWe	Ordered	Operational
NPD	22	1955	1962
Douglas Point	200	1959	1966
Pickering A 1,2	4 x 515	1964	1971
3,4		1967	1972-73
Bruce A	4 x 746	1969	1977-79
Gentilly II	637	1973	1982
Point Lepreau	630	1974	1982
Pickering B	4 x 516	1974	1983-84
Bruce B	4 x 756	1975	1983-87
Darlington	4 x 881	1978	originally 1984-87 now 1988-90

TABLE 2
SUMMARY OF EXPORT SALES

COUNTRY	DATE OF ORDER	DATE OF OPERATION	TYPE
India	1956	1960	NRX-type research reactor (CIRUS)
India	1963	1972	200 MWe power reactor (RAPP 1)
Pakistan	1964	1970	125 MWe power reactor (KANUPP)
India	1967	1981	200 MWe power reactor (RAPP 2)
Taiwan	1969	1971	NRX type research reactor
Argentina	1974		600 MWe power reactor (CORDOBA)
Korea	1976		629 MWe power reactor (WOLSUNG)
Romania	1979		629 MWe power reactor (CERNAVODA -1)
	1981		(CERNAVODA -2)

top ten large power reactors to the end of 1981 were CANDU units operated by Ontario Hydro. In 1981, the top six places for annual capacity factor were taken by Ontario Hydro CANDU units.

From its inception, federal and provincial governments have been heavily involved in the nuclear power program through direct funding, through the activities of Crown corporations such as Eldorado Nuclear Limited (ENL) and AECL, and through the creation of a regulatory framework under the Atomic Energy Control Act. Originally, government policy was to create a private sector capability for designing and building reactor systems. Consistent with this policy, the contract for design and construction of the Nuclear Power Demonstration plant (NPD) at Chalk River, Ontario was awarded to Canadian General Electric (CGE). Private sector companies, CGE and Deuterium Canada Ltd. (DCL), were also active in constructing Canada's first heavy water plants.

The role of governments, however, has become increasingly dominant. In 1959, for example, because of Ontario Hydro's unwillingness to commit itself to a single, private sector designer/supplier, AECL took over the design and project management of CANDU reactors beginning with the 200 MWe prototype reactor at Douglas Point, Ontario. Over time, AECL also assumed responsibility for reactor sales abroad and for heavy water production. AECL took over the DCL heavy water plant at Glace Bay, Nova Scotia, in 1978 and the CGE plant at Port Hawkesbury, also in Nova Scotia, in 1975. Ontario Hydro and public utilities in Québec and New Brunswick have assumed project management responsibility for reactors constructed in their respective provinces. Private industry has thus assumed the role of manufacturing components and providing engineering services for reactors designed by AECL and built by provincial utilities.

Although the domestic benefits of Canada's nuclear program have always been considered its principal justification, exports have been viewed as a natural extension of the domestic program (see Table 2). They have been considered necessary to give the program the scale to provide adequate returns on investment in R & D, to ensure the competitive worth of the CANDU system, to support the Canadian nuclear manufacturing industry through periods of slack orders, and to symbolize Canada's competence in high technology. Sales of reactors have also been important as a symbol of Canada's willingness to share an advanced technology which can contribute to diversification and security of energy supply for industrializing countries.

The Canadian Nuclear Industry

The nuclear industry in Canada, as a whole, employs about 36 000 people and can be divided into several groups (see Table 3). Research, development, and basic CANDU design work are performed by AECL, a federal Crown corporation. AECL also has the mandate for marketing the CANDU abroad. Construction and operation of reactors in Canada is the responsibility of the provincial electrical utilities, which also make the decisions in consultation with provincial governments, on whether and when to order them. Heavy water for the CANDU is produced both by Ontario Hydro and by AECL.

Uranium exploration and mining is carried out largely by private sector firms, although provincial and foreign governments are becoming increasingly involved. Uranium refining in Canada is carried out by Eldorado Nuclear Limited, another federal Crown corporation.

Finally, private sector firms manufacture the components for the CANDU, primarily for the nuclear part of the station, known as the Nuclear Steam Supply System (NSSS). They also undertake engineering and project management work for reactors outside Canada, and to a lesser extent in provinces outside Ontario. It is this latter group of private sector manufacturing and consulting firms, as well as AECL, which will be the focus of this review (see Figure 1, page 7).

TABLE 3
ESTIMATED TOTAL DIRECT EMPLOYMENT*
IN THE CANADIAN NUCLEAR INDUSTRY (1977)

Sector	Employment
Mining and Refining	5 470
Research and Development	3 280
Engineering and Design	4 110
Manufacturing	6 000
Construction	11 450
Operations and Maintenance	5 600
Public Administration	250
TOTAL	36 160**

*Source: Leonard & Partners. *Economic Impact of Nuclear Energy Industry in Canada*. Report to the Canadian Nuclear Industry. Toronto, 1978.

**A 1981 CNA study (to be published) estimated a total of approximately 38 000.

While these activities are all part of the nuclear fuel cycle, different parts of the industry exhibit quite different characteristics. The uranium mining industry, for example, depends for its sales on the number of reactors in operation in Canada and abroad. Therefore, while changes in the outlook for reactor sales will affect the outlook for the growth of sales in the uranium mining and upgrading industry, it is the continuing demand for uranium for reactors in operation, most of them located abroad, which sustains the industry.

Sales prospects for the reactor supply and heavy water sectors of the industry are determined by the decisions of utilities to add to generating capacity rather than by the number of reactors in operation. Capacity utilization within these sectors depends upon current orders by utilities, and any backlog of orders from previous years. Changes in demand conditions faced by utilities are thus rapidly translated into changes in commercial prospects for these particular segments of the industry. Capacity utilization in these segments of the industry is, therefore, highly variable and particularly sensitive to changes in demand for electricity.

The Reactor Supply Industry

DESCRIPTION

The total cost of a large (850 MWe) reactor unit was $1 billion in 1977. Of this, only about 17 per cent was accounted for by the reactor supply industry (see Table 4) whose output consists of those components and services which are required by the NSSS. This includes the reactor assembly, fuelling system, heat transport system, moderator system, safety system, control and instrumentation systems, and engineering services. The 1977 value of the NSSS components for an 850 MWe CANDU unit was estimated to be about $170 million, of which, it was estimated, approximately 75 per cent was spent in Canada. Appendix 3 provides a more detailed description of the CANDU reactor system.

FIGURE 1

EMPLOYMENT IN THE CANADIAN NUCLEAR INDUSTRY

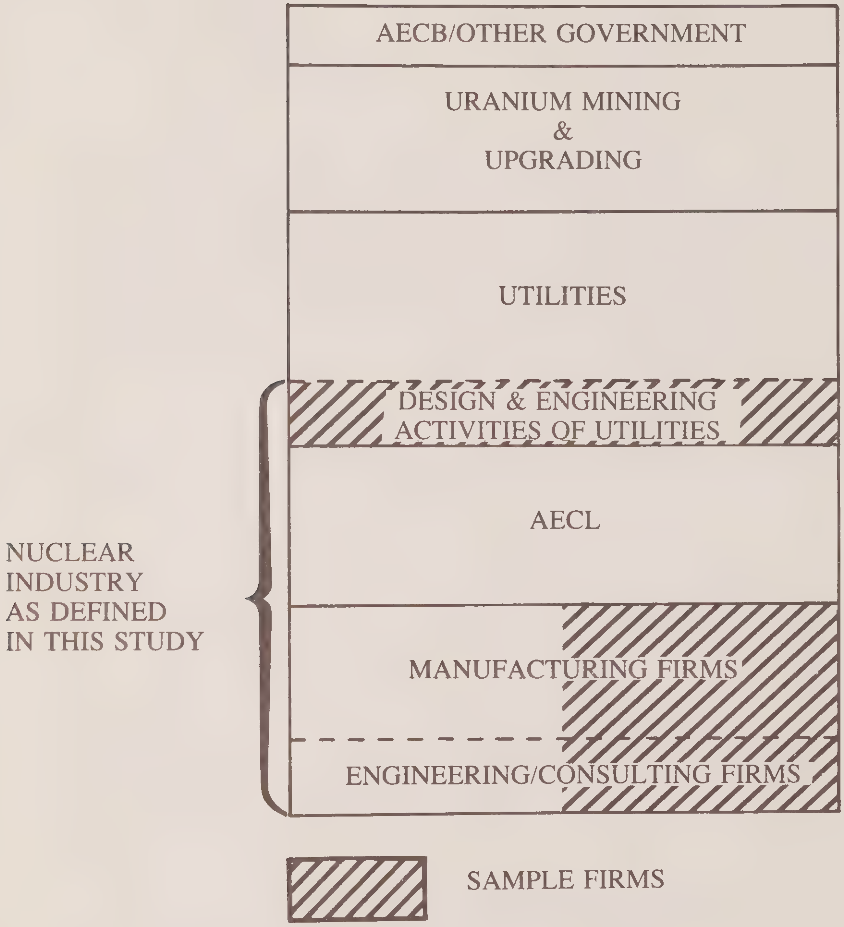

TABLE 4
COST BREAKDOWN FOR
MULTI-UNIT POWER PLANTS*
(4 x 850 MWe)

Component	% of Total Cost
Fuel, Heavy Water and Administration	26%
Financing	21%
NSSS	17%
Construction	16%
Balance of Plant	15%
Engineering	5%
	100%

*Source: Leonard & Partners.

Included in this definition of the reactor supply industry are AECL, and the engineering design and project management activities of those provincial utilities which use nuclear power, predominantly Ontario Hydro. AECL is a key supplier of CANDU-related services and is the owner of the CANDU design. Ontario Hydro undertakes engineering and other activities which are essential to the construction of nuclear reactors although it differs from other suppliers in being its own customer. Besides Ontario Hydro and AECL, the nuclear industry consists of a diverse group of companies, ranging in size from large, multiproduct firms (e.g. Canadian Vickers, Babcock and Wilcox, Canadian General Electric) to small, skilled machining firms (e.g. Donlee Nuclear, Bata Engineering). Total employment in the reactor manufacturing industry is about 6 000 people.

CHARACTERISTICS OF KEY SUPPLIERS

An intensive field survey was undertaken in conjunction with this study to obtain information about the nature of these firms and their prospects for the next decade. A sample of 18 key firms, chosen on the basis of their importance to the industry, and listed in Table 5, was interviewed by Woods Gordon, Ltd.

The key suppliers chosen reflect the characteristics of the nuclear reactor industry as a whole. The most important characteristic of the nuclear industry in Canada is high technology, distinguished by the importance to it of its design capabilities, specialized fabrication processes or techniques, sophisticated manufacturing skills, quality assurance procedures, and inspection and testing skills.

CANDU-related work is an important source of revenue for these companies, about half of which are foreign-owned. Over half the companies or their relevant divisions are more than 25 per cent dependent on CANDU business; on average, one third of their revenues are CANDU-related. However, because most suppliers produce non-CANDU related products, they would be unlikely to go out of business totally with loss of CANDU business; many would continue working in related high technology areas.

Excluding Ontario Hydro, the remaining 17 firms in the sample interviewed employ approximately 2 700 people in CANDU-related work, mainly in Ontario and Québec.

In all but four of the firms interviewed, nuclear component production shares facilities and equipment with other work. While certain facilities and equipment are now dedicated to nuclear products, they can, for the most part, be readily converted to other uses.

Sixteen of the 18 firms surveyed are manufacturers. They reported on average a total capacity for three reactor unit orders in shop per year. Minimum capacity utilization to maintain capability was stated on average to be one reactor order per year. Therefore, where a component is produced by two different suppliers, minimum capacity utilization ranges up to two reactor units per year.

TABLE 5
SUMMARY OF FIRMS INTERVIEWED

	Company	Major Product/Services
1.	Vickers Canada	Calandria vessel
2.	Dominion Bridge-Sulzer – Engineered Products	Calandria vessel
3.	Westinghouse Canada – Atomic Power Division	Fuel bundle tubes Calandria tubes
4.	Bristol Aerospace	Pressure tubes/Calandria tubes
5.	Chase Nuclear (Canada)	Pressure tubes (extruding)
6.	Noranda Metal Industries – Special Metals Division	Steam generator tubes Fuel bundle tubes
7.	Donlee Manufacturing Industries – Nuclear Division	End-Fittings
8.	Canadian General Electric – Power Generation Dept.	Fuelling machine
9.	Standard-Modern Tool – Manufacturing Division	Fuelling machine
10.	Babcock & Wilcox Canada	Steam generators
11.	Foster-Wheeler	Steam generators
12.	Bingham-Williamette	Pumps
13.	Borg-Warner (Canada) Byron-Jackson Division	Pumps
14.	Velan Engineering	Valves
15.	The Guelph Engineering Co.	Valves
16.	CAE Electronics	Control systems
17.	Canatom	Engineering Consulting
18.	Ontario Hydro	Engineering Consulting Operating

The ability of these firms to participate in the nuclear industry depends critically upon a highly trained work force. In general, maintaining design and engineering staff appears most important if capabilities in the nuclear area are to be maintained. Considerable importance is also attached to maintaining a quality assurance system with those technicians knowledgeable in this area, and to maintaining inspection and testing skills. A lower priority is attached to maintaining in-shop skills, except for a small proportion of direct production workers performing highly skilled operations.

STRUCTURAL AND ORGANIZATIONAL CHARACTERISTICS

A large number of institutions and companies contribute to the development of a CANDU nuclear power station. The industry structure has evolved largely in response to the needs of the domestic (mainly Ontario) market and questions have arisen as to whether it is in some ways ill adapted to successful negotiation of export sales or even domestic sales outside Ontario.* In other ways and in

*The most comprehensive development of this argument is found in the recent report *A Strategy for the Development and Strengthening of the Canadian Nuclear Industry* (March 1981) prepared by SECOR Incorporated and sponsored by Canatom, Velan Engineering, CAE Industries, the Royal Bank and Dominion Bridge – Sulzer.

specific markets, the unique structure of the Canadian nuclear industry may generate advantages for Canadian marketing efforts. These issues will be dealt with in more detail in subsequent sections of this review.

The Canadian nuclear industry is characterized by a significant degree of government involvement. For example, AECL, a federal Crown corporation, carries out the majority of nuclear-related R&D activities, as well as being responsible for development of the basic CANDU reactor design. Thus, AECL owns most of the designs relating to the CANDU 600 MWe nuclear supply system, the type of unit currently under construction in New Brunswick (Lepreau 1) and Québec (Gentilly 2) and AECL's standard export model. The electrical utilities which are provincial Crown corporations are also key players. The private sector provides a variety of manufacturing, construction and engineering services, depending on the market and the customer.

The way in which AECL, the electrical utilities and the private sector organize to design and build a nuclear generating station depends on the nature of the market in which they are operating. Three fairly distinct types of market can be identified: the Ontario market, the Canadian market outside Ontario and the export market.

(i) *Ontario:* Ontario Hydro is more than simply a customer of AECL. The utility assumes responsibility for a number of important design, engineering, and project management services. Ontario Hydro, for example, has designed its own version of the CANDU reactor (the 850 MWe units being built at Darlington). Ontario Hydro and AECL act together as main contractors during construction, leaving private industry to act primarily as a supplier of manufactured components.

(ii) *The Canadian Market Outside Ontario:* Outside Ontario, other Canadian utilities play less of a role in project management. New Brunswick, with its much smaller system size, does not have the resources to duplicate Ontario Hydro's role. Hydro Quebec, although a very large utility, has chosen not to do so. AECL, therefore, has played a much larger role in both the Lepreau I and Gentilly 2 units. The private sector also tends to play a somewhat larger role in these markets, providing, for example, more of the engineering, design and project management services required to put a plant in place. Thus, Canatom owns certain designs relating to the balance of plant for the CANDU 600 MWe station. Nuclear steam supply equipment is manufactured by a large number of private companies, generally on a two-supplier basis.

(iii) *Export Sales:* AECL assumes primary responsibility for marketing CANDU reactors abroad, mainly the standard 600 MWe CANDU unit. The private sector again acts as a supplier of manufactured components, engineering, and project management services depending on the capabilities and objectives of the importing utility or agency. Additional government involvement is generally required through the Export Development Corporation (EDC). It provides funds at competitive rates to help secure export sales. Therefore, EDC and the federal export credit policy it implements are critical structural features of doing business abroad, especially as competitive financing has become a normal requirement to making large sales in developing countries.

The specific organizational approach depends on the nature of the market and the desires of the customer. In Korea, AECL is responsible for overall project management under a turnkey contract to deliver a nuclear generating station. The balance of plant contract rests with the importing utility (KEPCO) and a British supplier. In Romania, Romanergo, the importing agency, purchases engineering services from AECL and equipment from Canadian manufacturers.

This structure is the result of an evolutionary process and the nature of Canadian industry in general. AECL was established and grew as a research and engineering company. It entered into reactor marketing at home and abroad as an extension of its original development functions.

As purchasers of nuclear-related goods and services, Ontario Hydro and AECL encouraged and used supplier competition to secure the best possible prices and performance from Canadian suppliers. This led to the creation of a competitive industrial structure in which there were at least two suppliers for almost all the major CANDU components.

Projected levels of excess capacity make changes in the two-supplier structure of Canada's nuclear industry virtually inevitable. Although some difficult adjustments will be required on the way, the achievement of a rationalized single-supplier is not necessarily undesirable. Other reactor vendors are able to maintain cost effectiveness with single suppliers through careful cost control and through the test of international competition.

Whether based on single or multiple component suppliers, the decentralized industry which has evolved in Canada requires coordinated interaction among many independent suppliers of goods and services to develop a project. The methods of coordination have differed between projects, and in some cases problems have arisen. The overall impact of industry structure on performance will be discussed at greater length later.

The Heavy Water Industry

Heavy water is a key component of the CANDU Nuclear Power System. It is the use of heavy water as a moderator which enables the CANDU reactor system to be fuelled with unenriched uranium. The initial charge of heavy water, roughly 500 Mg (500 tonnes) for a 600 MWe CANDU reactor, accounts for approximately $150 million of the front end capital investment for the reactor system. Subsequent loss make-up requirements are small; typically 1% or less of inventory per year.

Heavy water is produced in large-scale, capital intensive plants utilizing a continuous chemical exchange process with hydrogen sulphide, followed by distillation. The exchange process is energy-intensive, using large amounts of process steam and electricity.

The supply of heavy water for the Canadian nuclear program was originally a private sector endeavour. To this end, the government supported both Deuterium of Canada Limited (Glace Bay, N.S.) and Canadian General Electric (Port Hawkesbury, N.S.) in their initiatives to construct and operate heavy water plants. Both of these plants experienced severe technical and financial problems and AECL subsequently purchased them.

In 1968, with the forecast of significant growth in the Ontario program, AECL constructed the Bruce A heavy water plant, selling this plant to Ontario Hydro in 1973. In response to the increasing heavy water demands anticipated in the early 1970's, AECL also commenced construction in 1974 of a plant at La Prade, Québec.

As the decade progressed, however, it became increasingly apparent that the demand forecasts which formed the basis for the rapid expansion of heavy water capacity were not going to be realized. Rates of growth in electrical demand and therefore reactor orders fell below anticipated levels and continued lower than expected throughout the decade. The result was considerable overcapacity in the heavy water industry.

The reduction in forecast demand for heavy water in the mid 1970's, coupled with improved production capability from AECL and Ontario Hydro facilities, led to the decision in 1978 to suspend further construction of the La Prade heavy water plant and to mothball this facility. Also faced with the possibility of a chronic oversupply problem, Ontario Hydro decided about the same time to reduce its production capacity expansion program and mothball the Bruce D plant. It had earlier cancelled plans for its Bruce C plant.

At present, heavy water is being produced at four plants: two located at Ontario Hydro's Bruce site (Bruce A and B); and two located in Cape Breton, operated by AECL Chemical Company (see Table 6).

TABLE 6
CANADIAN HEAVY WATER CAPACITY

PLANT	NOMINAL CAPACITY (tonnes/year)	STATUS
Ontario Hydro		
Bruce HWP-A	800	– operating
Bruce HWP-B	800	– operating
Bruce HWP-C	(800)	– cancelled during planning stage
Bruce HWP-D	(800)	– 1/2 mothballed 1/2 suspended
AECL		
Glace Bay HWP, Nova Scotia	400	– operating
Port Hawkesbury, Nova Scotia	400	– operating
La Prade, Québec	(800)	– mothballed before completion

3. THE OUTLOOK FOR THE NUCLEAR INDUSTRY: DOMESTIC PROSPECTS

Introduction

The nuclear industry is aimed toward the production of a single product – electricity. As such, it is acutely sensitive to demand conditions facing the provincial electrical utilities. Therefore, it is the outlook for electricity load growth in Canada which is examined first.

Historical Growth of Demand for Electricity

From 1963 to 1974 electricity demand in Canada grew at 7.4 per cent per annum (see Table 7). This rapid growth reflected strong economic growth over the period, a declining real price of electricity, and a substantial decrease in the price advantage which oil maintained relative to electricity.

For 1974-78, growth rates of electricity consumption declined to 4.4 per cent per annum. Nevertheless, electricity has continued to increase its share of the total energy market.

It had been anticipated that higher oil prices would stimulate the substitution of electricity for petroleum fuels during the 1970's. Instead, higher prices reduced economic growth and, in so doing, more than counteracted the substitution effect. Thus, the net effect of higher oil prices was to reduce electricity demand growth. Additional factors acting to slow the growth rate of electricity demand included slower population growth, an increased general interest in energy conservation, and increases in the real price of electricity.

This unanticipated decline in electricity growth rates, combined with the momentum of ambitious expansion plans based on pre-1973 growth rates, has created significant excess generating capacity in

important electrical utilities. This in turn has led to a postponement of existing expansion plans and deferral of decisions regarding future increases in capacity.

Electricity Growth and Capacity Requirements 1980-2000

The outlook for reactor sales in the domestic market is detemined by the rate of load growth in relation to generation alternatives. The EMR forecasts of electrical demand growth are based on the department's Inter-Fuel Substitution Demand Model. The model produces forecasts which attempt to take into account the myriad of influences which affect electricity demand growth: economic growth, the price of electricity, the price of other energy sources, and a variety of other influences on demand such as population growth and housing stock characteristics. The most important influence on the growth of electricity demand is the growth of the economy. For this reason, two forecasts of growth rate of the Gross National Product are considered.

TABLE 7
SUMMARY OF RECENT TRENDS RELATED TO ELECTRICITY CONSUMPTION IN CANADA

GROWTH RATES	1963-1974	1974-1978
Electricity consumption	7.4%	4.4%
Gross National Product	5.6%	3.8%
Real electricity prices	–3.4%	6.2%
Real oil prices	2.9%	7.2%
Real gas prices	–2.0%	11.2%
Electricity consumption as a percentage of energy demand	13.0% (1963)	18.0% (1978)

TABLE 8
ASSUMPTIONS ABOUT ECONOMIC PERFORMANCE
(GNP Growth in % Per Annum)

	EMR Base Case	EMR High Growth Case
1980-1985	3.1	3.6
1986-1990	3.2	4.0
1991-2000	2.6	3.5

The base case forecast corresponds to the Department of Finance's medium term forecast (Table 8). It reflects economic growth at rates below recent averages; these lower growth rates are attributable to the impact of increasing energy prices and underlying demographic changes.

The high growth case, taken from the National Energy Board, averages 0.8 per cent per annum higher than the base case over the two decades.

According to the base case forecast, Canadian electricity demand will grow by 3.3 per cent per annum to 2000 (Table 9). This is well below historic experience despite continuation of the trend towards a larger share for electricity in total energy consumption. The lower forecast growth rate is attributable to lower forecast rates of growth in economic activity, to rising real costs of electricity production, and to continuing efforts at conservation.

The EMR high growth forecast yields an average annual rate of growth of 3.8 per cent, still below the pre-1977 growth rates.

Table 9 also summarizes forecasts of electrical demand growth made by individual provincial utilities. These differ from the EMR forecasts because each utility makes its own assumptions about expected movements in the factors which determine electrical demand growth: economic activity, population growth, conservation, and substitution. The utilities' forecasts of electrical consumption, although reduced in light of recent experience, are higher than both the base case and high growth case EMR forecasts.

Utilities plan to meet increases in demand by adding to generating capacity as required. By making assumptions about reserve requirements and the future shape of the daily and seasonal pattern of electricity demand, the growth rates of electrical energy consumption in Table 9 can be converted into requirements for additional generation capacity. Table 10 shows existing and committed capacity and Table 11 indicates the capacity requirements for 1990 and 2000 by province and type.

Implications

GENERAL

The forecast results indicate, first, that under each electrical load growth scenario, substantial additions to capacity beyond existing and committed will be required by 2000, ranging from 18 704 MWe under the base case scenario to 58 020 MWe based on the utility forecasts. More than 65 per cent of additions to capacity occur in Québec and Ontario, markets in which CANDU is an economically attractive alternative.

However, the forecasts also show that additions to capacity are not required continuously over the forecast period. Under each scenario, few or no additions to capacity beyond the committed program are required to 1989, most uncommitted requirements occuring in the 1990-2000 period.

TABLE 9
FORECASTS OF GROWTH RATES IN ELECTRICITY CONSUMPTION: (1980 – 2000)
(kwh)

	Annual Growth Rates (%)		
	EMR BASE CASE	**EMR HIGH GROWTH CASE**	**UTILITY* FORECASTS**
Atlantic Region	2.3	2.5	4.4
Québec	3.8	4.3	5.6
Ontario	2.8	3.2	3.1
Manitoba	2.6	3.0	3.2
Saskatchewan	3.1	3.5	4.3
Alberta	4.1	4.7	6.2
British Columbia	3.5	4.0	4.5
Canada	3.3	3.8	4.4

* Updated July 1981.

TABLE 10
GENERATING CAPACITY: EXISTING AND COMMITTED*
(MWe)

Province	**Existing** (end 1979)	**Committed** (1980-1990)
Newfoundland	7 124.3	184
Prince Edward Island	118.2	0
Nova Scotia	1 878.8	173.5
New Brunswick	2 697.5	740.0
Québec	18 230.0	17 324.0
Ontario	25 716.2	9 874.2
Manitoba	4 134.5	1 170.0
Saskatchewan	2 080.7	600.0
Alberta	5 365.1	2 300.0
British Columbia	9 462.2	3 205.0

Source: Canada. Energy, Mines and Resources Canada. *Electric Power in Canada*. Ottawa, 1979. (Report ER80-7)
*Name-plate rated capacity.

The forecasts indicate, therefore, a clear potential role for nuclear power in the 1990's, but highlight the prospect of a shortage of domestic orders for additional generating capacity in general, and reactor units in particular, over the next few years.

Another general feature of the forecasts is the sensitivity of capacity requirements to small changes in underlying assumptions about economic growth rates. For example, the 0.8 per cent per annum difference in average GNP growth rates between the two EMR forecasts leads to an 11 000 MWe difference in capacity requirements in 2000 – almost fourteen 850 MWe reactor units.

However, as will be shown in the next section, the provinces most likely to commit new nuclear units need not undertake new construction commitments until the latter half of the 1980's, according to EMR forecasts. The provinces which are likely to commit new capacity soon are those which are unlikely to choose nuclear systems. Thus, in spite of significant apparent demand for new nuclear capacity by 2000 and beyond, the prospects for early orders based on domestic demand appear low.

Forecasts are always characterized by a degree of uncertainty because they are sensitive to assumptions about the course of underlying economic factors, which can behave unpredictably. Therefore, despite the generally pessimistic short term outlook for the industry implicit in the demand forecasts presented here, there is always the possibility of an unanticipated resurgence in economic growth or a massive swing by consumers in favour of electrical energy, or some other unforeseen factor, which could make these forecasts quite wrong. For example, technological development of lower cost electrical and hybrid heating systems could significantly improve the economic attractiveness of electricity vis-à-vis other forms of home heating, leading to increases in the demand for electricity, which are not anticipated in the demand estimates of Table 9.

In addition to its role in new generating capacity, there may be some economic justification in some scenarios for nuclear capacity to be built to replace existing oil or even coal-fired capacity. Such a possibility is more likely for electricity exports to the United States, especially the North-East where oil-fired capacity is a dominant feature of the utility scene. Estimates of nuclear growth to replace existing capacity have not been included in the analysis persented in this section.

TABLE 11
CAPACITY REQUIREMENTS
Beyond Existing and Committed*
(MWe)

	EMR BASE CASE		EMR HIGH GROWTH CASE		UTILITY FORECASTS	
	1990	**2000**	**1990**	**2000**	**1990**	**2000**
Altantic Region	(1756)	(207)	(1608)	303	359	4169
Québec	(1630)	11002	(66)	15882	6953	33288
Ontario	(6009)	2226	(4006)	4861	(4023)	4585
Manitoba	(271)	(438)	(162)	(82)	366	518
Saskatchewan	(71)	1051	4	1406	1053	2378
Alberta	(168)	3656	193	5050	1404	7221
British Columbia	(3450)	769	(2979)	2468	(599)	5861

*Brackets indicate capacity requirements less than existing and committed.

In assessing the outlook for the nuclear industry, 2000 was chosen as a convenient terminal date, reflecting the focus of this study on the short term problems and medium term viability of the nuclear industry. In reality, of course, the need for additions to capacity will not end with the turn of the century. Decisions taken today with respect to generating plants may not result in capacity onstream for 12 to 15 years. Therefore, capacity requirements beyond 2000 are important in assessing sales prospects for the industry in 1990 or so. These are not, however, explicitly taken into account in this review.

PROSPECTS FOR NUCLEAR ENERGY BY REGION

Introduction

The economic desirability of the generation alternatives affecting utilities varies significantly from region to region in Canada. For example, while the price of nuclear power is more or less constant across the country, the price of coal varies markedly. In areas of the country where there are large coal deposits which can be easily mined, such as Alberta, coal is relatively inexpensive compared to nuclear. On the other hand, in areas of the country which are located long distances from coal (Ontario, Québec) the high cost of transportation makes coal much less attractive. As well, the cost of hydro varies from region to region and location to location within each region. In some parts of the country (British Columbia, Manitoba, Québec, and Newfoundland) some remaining hydro sites are economically attractive compared to nuclear. In other areas, particularly Ontario, economic hydro sites have been largely exhausted.

In summary, it is difficult to generalize about the nature of generation alternatives facing Canadian utilities. Nuclear, coal and hydro are the major alternatives but their relative economics must be assessed on a region by region basis.

British Columbia

Peace River and northern hydro sites, as well as coal-thermal generation at Hat Creek, are available at prices either below or competitive with nuclear. The development of these options would satisfy demand until at least the turn of the century under all three electricity demand forecasts. Only if environmental considerations impose severe physical or economic constraints on coal and hydro generation is there any real opportunity for nuclear generation before 2000.

Alberta

Alberta has plentiful reserves of relatively inexpensive coal. Even with more stringent and costly environmental regulation of coal, the economics of nuclear are not likely to become attractive over the next two decades. Major changes in policy to conserve farmland, if implemented, could affect the present assessment of coal supply in Alberta. There is also the possibility of commercializing the organically cooled CANDU to supply process energy for tar sands extraction, but no decision is imminent. On balance, installation of nuclear generating capacity in Alberta is unlikely before the end of the century.

Saskatchewan

There does not appear to be much scope for nuclear power in Saskatchewan because of its limited system size, coal deposits, and potential access to more economic energy sources from neighbouring provinces.

Manitoba

Manitoba has a well-defined hydro development strategy, which will meet demand until at least 2000 and perhaps longer, depending on the growth rate of electrical consumption. With the completion of the Churchill River Diversion and Lake Winnipeg regulation, the marginal cost of hydro development is relatively attractive compared with coal or nuclear alternatives. Although there are technical arguments in favour of building some amount of generating capacity in the south of the province to balance the long transmission lines from northern hydro sites, it currently seems improbable that Manitoba will build any nuclear stations this century.

Ontario

Ontario is a critical market for nuclear reactors. First, it has a large and well developed successful nuclear power program. Second, the limited availability of generation alternatives such as low cost coal and hydro makes nuclear energy economically attractive for base load electricity generation. On the other hand, low and declining load growth forecasts limit the size of the incremental market for nuclear reactors in the near term.

The potential role for nuclear energy depends upon load growth, upon the existing and committed expansion program, and upon the utility's preferences with respect to the coal/nuclear mix. The three demand forecasts and the current expansion program are summarized in Figure 2. The implications for nuclear power are given in Table 12.

Depending on which forecast is used, Ontario's projected demand will require building from two to four 850 MWe reactor units beyond Darlington (six, if incremental capacity were 100 per cent nuclear), all to be in operation by 2000.* As illustrated in Figure 2, it appears that no new capacity beyond Darlington, either coal or nuclear, will be required before the mid-1990's. In any case, with Ontario having established a requirement for public environmental hearings to be held for each new nuclear station, it is thought unlikely that construction of a new nuclear project could be started before 1985. It does not appear likely that the first post-Darlington work will enter the suppliers' shops much before 1986 unless some form of stockpiling program is initiated to support particularly hard pressed companies.

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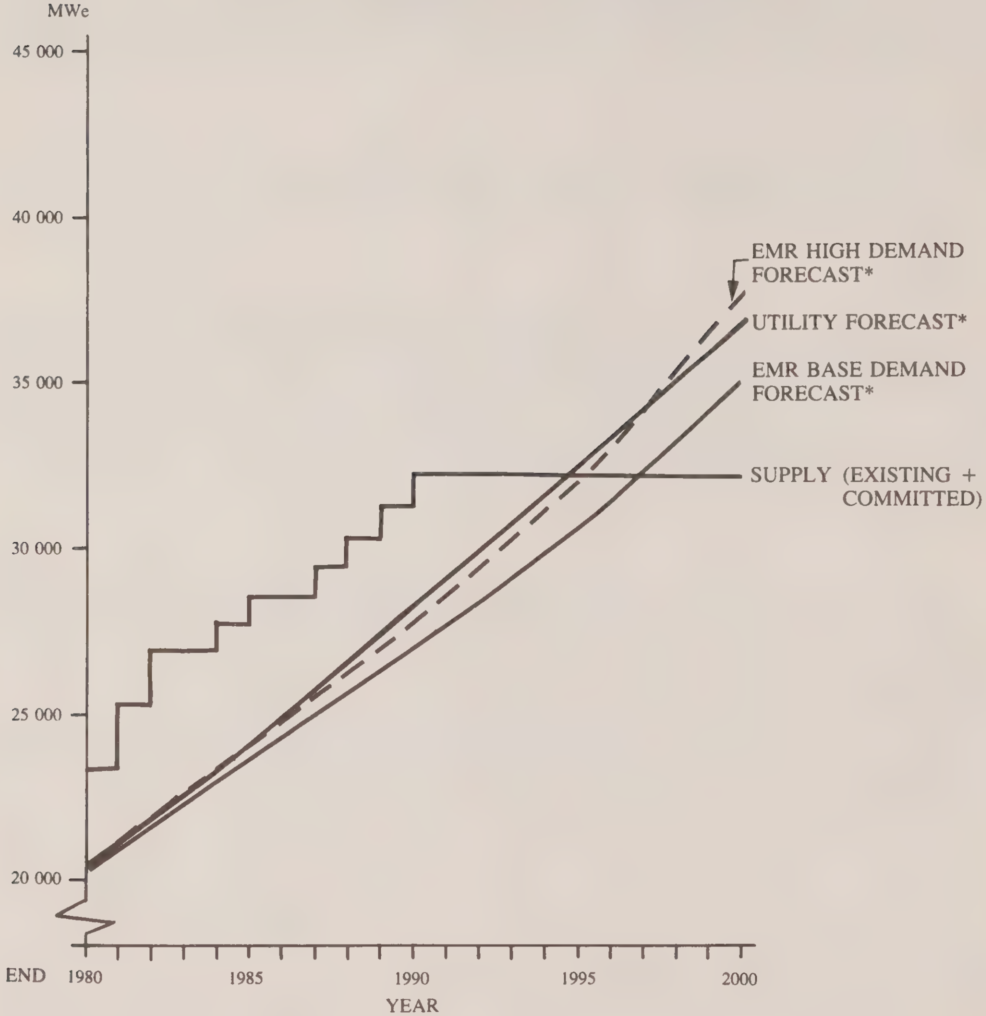
*Coal and nuclear are not the only alternatives for meeting load growth in Ontario. Increased industrial co-generation, for example, is also a possibility. However, according to a recent EMR study, the upper limit of economically attractive undeveloped co-generation in the province is about 325 MWe, an amount too small to affect markedly the utility's nuclear expansion plans. See: Acres-Shawinigan Ltd. *Study of the Potential for Co-Generation in Canada*. Ottawa, Energy, Mines & Resources Canada, Conservation and Renewable Energy Branch, 1979.

FIGURE 2

ONTARIO SUPPLY AND DEMAND FOR GENERATING CAPACITY



* includes 25% reserve ratio

TABLE 12
POTENTIAL DEMAND FOR REACTOR UNITS*
ONTARIO TO 2000

Coal Nuclear Mix	EMR Base Case	EMR High Growth	Utility Forecast
1/3 nuclear / 2/3 coal	1	2	2
2/3 nuclear / 1/3 coal	2	4	4

* Assumes 850 MWe Units

Another possibility which could lead to some early commitment for new nuclear capacity in Ontario is construction of plants for the export of electricity. The provincial government has shown some support for this idea if suitable markets can be developed. The utility is currently investigating firm sales from a coal-fired plant as its first significant venture into this form of export (previous extensive sales have been on a short term economy exchange basis). However it is too early to predict whether new nuclear capacity will be built for this export market; therefore, none has been included in the projections in this study.

Québec

Hydro-Québec, as one of the two largest utilities in Canada in terms of installed capacity and in-province demand, is a potentially very important domestic market for nuclear generation. However, at the same time it may well be the most uncertain.

Québec commenced a nuclear program in the mid-1960's, with the Gentilly-1 prototype reactor which used a heavy water moderator and a boiling light water coolant. This unit was completed in 1971 but has never operated commercially. It is owned by AECL and operated by Hydro Québec. Gentilly-1 is currently shut down and is not licensed for operation. Hydro Québec ordered a conventional CANDU 600 MWe unit in 1972, Gentilly –2, the first unit of several sold by AECL at about that time. It is expected to start up in 1982.

Québec had been expected to proceed into a larger nuclear program, perhaps building a four-unit station similar to Ontario Hydro's Darlington. Construction was started on a large heavy water plant (La Prade) at the Gentilly site to supply Québec's need plus part of anticipated export demands, but the partially built plant was mothballed in the late 1970's as demand for heavy water declined.

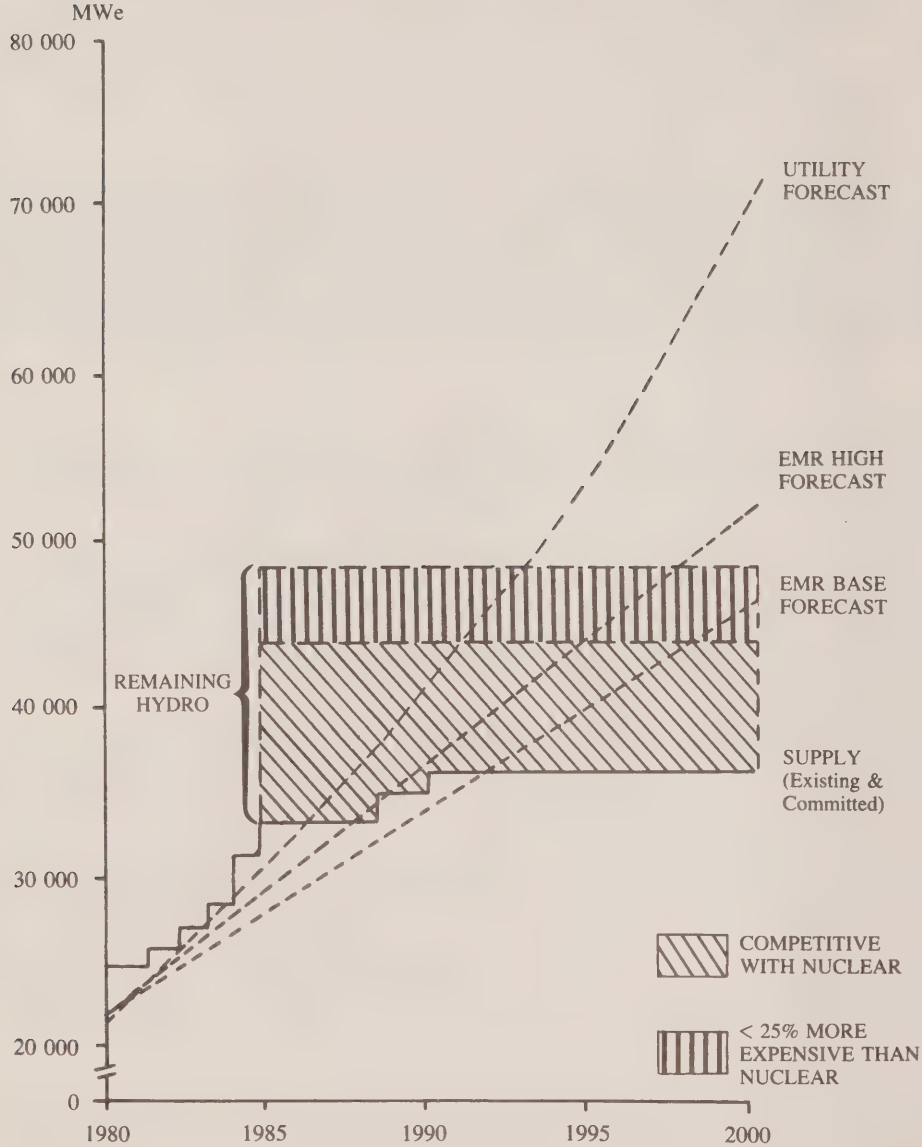
The current uncertainty in the Québec program arises from the substantial amount of hydro power which Québec still has available and the recent sharp declines in electricity growth rates; the utility forecast of 5.6% per annum reported in Table 9 has very recently been lowered to 4.7% per annum.

Hydro-Québec is currently committed to develop a little over 10 000 MWe of additional hydro beyond James Bay Phase 1 (see Appendix 1). This capacity is less expensive than nuclear. Beyond this, a further 5 000 MWe of hydro is available at a cost up to 25 per cent more expensive than nuclear. Québec's hydro potential beyond these amounts, perhaps 10 to 20 000 MWe, ranges up to 400 per cent more expensive than nuclear.

If the utility were to choose to develop the total of 15 000 MWe of hydro which is up to 25% more expensive than nuclear, this would provide sufficient base load capacity for the remainder of the century under any of the load growth forecasts (EMR base and high cases and the utility forecast, as shown in Figure 3). The only reasons for Québec to extend its nuclear program at an earlier date would be:

FIGURE 3

QUEBEC
SUPPLY AND DEMAND
FOR GENERATING CAPACITY *



* includes 15% ratio; corresponds to forecast in Table 9.

- dramatic increases in the province's load growth again in the near future;
- a choice to dedicate some of its capacity to supply power for long term exports to U.S. markets;
- to re-enter the nuclear construction program at a slower and more readily accommodated pace. In planning terms, this would allow a gradual phase in of nuclear capacity before economically attractive hydro capacity is exhausted.

From this analysis it seems probable that the next round of nuclear orders from Québec will not occur until the 1990's for in-service dates after the year 2000. The most optimistic scenario that appears to be viable is for orders to be placed in the mid-to-late-1980's for the first two units to come into service in the late 1990's as the utility slowly builds up its nuclear base for a larger program early in the next century.

An additional problem complicating the outlook for nuclear energy in Québec is the state of relations among the provincial government, Hydro-Québec and AECL. A considerable improvement in AECL/Hydro-Québec relations may be required if nuclear energy is to expand in the province. AECL is taking a number of initiatives in this direction.

Atlantic Region

In the Maritime region there is also uncertainty concerning the future role of nuclear power. Much depends upon the relative costs of coal and nuclear (which depend in part on whether local or imported coal is used, and the increased environmental protection costs imposed on burning coal), and the development of acceptable institutional arrangements for sharing nuclear capacity among Nova Scotia, New Brunswick, and Prince Edward Island, as well as the evolution of public acceptability. New Brunswick is in the best position to continue nuclear expansion by building a second 600 MWe CANDU unit at the Lepreau site. The site was designed and environmentally assessed for two units, although only one is currently being built.

The viability and timing of nuclear generation increments in New Brunswick depend upon three rather uncertain variables: load growth, duration of supply from Québec, and successful energy export contracting. The latter is probably the decisive factor because it can be varied at the planning and contracting stage in response to local requirements, and is an important determinant of the financial viability of New Brunswick nuclear generation units. The export market provides significant benefit to the utility in power sharing during initial years of operation, prior to the return of the unit to domestic use.

It is not clear in what year Lepreau 2 will be committed. Current utility forecasts indicate that New Brunswick will not require additional generating capacity before 1995. Although nuclear power may be cheaper than some oil and coal-fired capacity being used in the province before that time, it appears unlikely that Lepreau 2 will be brought into service earlier unless a significant fraction of its output is sold on firm contracts to U.S. markets. However there appears to be a real possibility of suitable export sales, making an in-service date as early as 1989 at least a theoretical possibility, and opening the possibility of up to two further units at the same site by 2000, to supply additional U.S. markets and perhaps displace fossil fuel burning plants in the Maritime provinces.

Nova Scotia is likely to pursue the development of its indigenous coal reserves and does not currently plan an early entry into a nuclear program.

Prince Edward Island will probably buy most of its electricity from its neighbours through undersea cables for the foreseeable future. Although some of this may be supplied contractually from nuclear plants, the size of the P.E.I. market will not measurably impact on demand for nuclear power in the region.

Newfoundland's island grid is too small to accept large nuclear stations, at least for some time. Once it interconnects to the mainland (Labrador) in conjunction with the Lower Churchill development, it will not need nuclear power. Thus the province is unlikely to initiate a nuclear program this century.

An Alternative Approach

It should be noted that the forecasts presented, and the conclusions drawn from them, are based on a conventional economic approach to demand forecasting. This approach assumes that firms and consumers will continue to make electricity consumption decisions based on preferences, incomes, and the prices in the energy market place. Utilities then attempt to satisfy resulting energy demands by ensuring adequate capacity is available when required. It is when making these capacity additions that utilities, and society as a whole, are confronted with difficult choices between coal, hydro and nuclear energy, all of which have some cost in terms of disruption of the natural environment and threats to public health and safety.

There are alternative approaches to demand forecasting which seek to avoid the costs of adding to generating capacity. They question the need for, and desirability of, continued demand growth.

While alternative approaches vary widely, they can generally be termed target or goal oriented approaches. Two steps are generally involved. First, an explicit target rate of growth in electricity consumption is established based on judgments about the need for electricity and the economic, environmental, and social costs of generating it. The goal may be, for example, zero growth in demand. This allows society to avoid entirely the necessity for choosing between coal, nuclear, and hydro generating alternatives. Second, a number of measures are developed and implemented – pricing, promotion of conservation, and mandatory measures such as rationing and electrical load management. The intent of these measures is to ensure that the growth targets are achieved.

The target approach raises some difficult questions. Who determines these targets and how? How can the economic and political problems of implementation be overcome? How large are the gains or losses in economic efficiency which such an approach might involve? These issues would require considerable examination before such an approach could be adopted.

Policy induced zero demand growth is a possibility. It would, however, involve an unprecedented degree of government intervention as well as fundamental changes in lifestyle, changes which to date the majority of Canadians have given no indication they are prepared to make.

Summary

The only prospects for early orders for CANDU units in Canada appear to be in the three provinces which currently have reactors in operation or under construction, namely Ontario, Québec, and New Brunswick. Even in these markets the first new orders may still be several years away. The market in New Brunswick (and the Maritimes in general) will not be very large under any scenario, and west of Ontario there is not much prospect that nuclear energy will be needed in this century. The level of ordering over the next few years for this domestic market, therefore, appears to be too low to sustain the nuclear supply industry as it is at present constituted. On the other hand, Ontario's recent initiatives to accelerate substitution could lead to several more units being required in Ontario late in this century and hence for orders late in the 1980's. There are reasonable prospects for nuclear programs in Québec, in western Canada and in Nova Scotia early in the next century, which will require that orders be placed in the 1990's.

Thus, while there may well be an adequate level of orders in the latter part of the decade and the 1990's, it is clear that the domestic market will be difficult for the next few years.

4. THE OUTLOOK FOR THE NUCLEAR INDUSTRY: EXPORT PROSPECTS

Introduction

While the domestic market has been by far the most important source of demand for the Canadian nuclear industry, the export market is not unimportant. Although success in that market has continued to prove elusive, export sales in principle represent a natural extension of, and support for, the domestic nuclear program. They permit economies of scale and the spreading of R&D and other overhead costs over a larger number of units. They offer an opportunity to earn foreign exchange and profits for domestic firms, while ensuring that the CANDU remains competitive. They also provide important experience in the management of international megaprojects based on Canadian technology. Finally, the demonstration effect from reactor sales could enhance Canada's ability to sell other high technology exports.

Canada's policy on reactor exports must also be outward looking. Other countries are actively interested in obtaining the nuclear technology which they see working so well in Canada, to secure their own energy supply and to obtain the benefits of industrial development. A policy of denying other countries access to an advanced and durable energy supply system would run counter to Canada's traditional foreign policy of sharing its technology. This is especially true for rapidly industrializing countries, many of which face an oppressive balance of payments burden generated in part by the use of imported oil for the generation of electricity. Denial would also undermine our commitment to the Non-Proliferation Treaty under which we have agreed to provide nuclear technology for peaceful purposes to those countries which renounce the acquisition of nuclear weapons and accept fullscope international safeguards on all their nuclear programs.

At the same time, however, the export of reactor equipment, technology, and other nuclear materials poses problems which require an often difficult balancing of costs, risks and benefits. Of most concern to the public has been the potential role of nuclear reactor exports in the proliferation of nuclear weapons. For this reason Canada exports reactors only to those countries which agree to strict bilateral and international nonproliferation requirements.

Influences on Export Performance

INTRODUCTION

As a result of lower rates of growth of electricity demand, almost all vending countries are experiencing excess capacity in their reactor supply industries. The export market for reactor units has become, as a consequence, extremely competitive: Canada will have a difficult time even with substantial changes in policy and marketing, making major gains in the export market. More specifically, the success of Canadian efforts in the export market will be determined by a number of complex influences: the size of the market; perceptions of economic and technological suitability of CANDU; skill in marketing and project management; and the government's attitude and policies.

THE MARKET

The size of the export market for nuclear reactors is, like the size of the domestic market, largely determined by the rate of growth of demand for electricity in importing countries, and the generating alternatives available to them.

Like Canada, most industrialized countries have experienced a significant decline in electricity growth rates since 1974 as GNP growth has slowed and energy conservation has been pursued. Growth

rates in developed countries have fallen from historical averages of around 7 per cent to current levels of from 2 to 4 per cent. This has reduced the size of the market for reactor units.

Worldwide, reactor orders placed from 1975-1979 averaged only one third of the high levels maintained from 1971-1974.* As well as limiting the potential size of the nuclear market, this decline in electricity demand has created fierce international competition for reactor sales. With domestic prospects bleak, reactor manufacturers have turned to the export market as an increasingly important factor in sustaining commercial viability. France, with an aggressive domestic nuclear power program which will add five GWe each year to domestic capacity, is also extremely active in the export market.

Over the next 10 years or so, a period critical to the commercial health of the nuclear industry, prospects will remain uncertain. In general, projections indicate that electricity growth rates will vary from as low as 2 per cent to 10 per cent or higher until 2000, with highly industrialized countries near the lower end of the range and newly industrializing countries towards the upper end of the range.

Many of the newly industrializing countries have been experiencing very rapid electricity growth rates, some in the order of 10 to 15 per cent annually. Projected demand growth, and other information for several countries which are considered to be prospects for CANDU sales, is set out in Table 13.

TABLE 13
ELECTRICITY GROWTH RATES IN SELECTED COUNTRIES

Country	Recent Electricity Demand Growth Rate (%/a)(1)	Projected Future Growth Rate (%/a)(6)	Nuclear Capacity Installed or Committed (MWE)(7)	Ratified NPT
Argentina	7.1		1600	no
Australia	6.1	7.0	0	yes
China	13.8(3, 4)	5	0	no
Denmark	5.9	5.6	0	yes
Greece	8.8	8.7	0	yes
Indonesia	10.5(2)	14	0	yes
Ireland	6.9	9.1	0	yes
Mexico	8.3(3)	12.4	1300	yes
Netherlands	2.9	3.9	500	yes
Philippines	6.6(2)	10	600	yes
Portugal	6.4	7.6	0	yes
Romania	6.9(2)	6	600	yes
South Korea	15.1	9.4	7400	yes
Taiwan	13.4(5)	12.0	5000	no(8)
Turkey	15.1(2)	13.3	400	yes
Venezuela	8.2(2)		0	yes
Yugoslavia	7.2(2)	7.6	600	yes

Notes:
1. Average growth rates from 1974 to 1979 unless otherwise noted. Data from (2) and (3).
2. UN Statistical Year Book (1978) for period 1974-77.
3. World Energy Index 1979 Annual Issue. Business Information Display, Inc..
. Data available to 1978 only.
4. Smil, V. *China's Energy*. N.Y., Praeger, 1979. For the period 1964 to 1977.
5. Taiwan Power Company Annual Reports.
6. Individual country assessments as compiled by AECL or reported by specific missions.
7. Nuclear News. Data to September 1980.
8. Taiwan signed NPT but has been unable to ratify it because of derecognition. However, nuclear facilities in Taiwan are being inspected by the IAEA under its normal safeguards system.

*Lönnroth, M. and Walker, W. *The Viability of the Civil Nuclear Industry*. N.Y., The Rockefeller Foundation/The Royal Institute of International Affairs, 1979.

In many developing countries electricity supply runs well below demand so the growth rate is limited only by how rapidly new capacity can be built. This in turn is generally limited by economic and logistic factors which vary from country to country. Also, some countries will add nuclear capacity to displace oil-fuelled generation, and again these additions will be limited by factors other than growth in electricity demand. Thus, although growth in electricity demand can be important, it is not possible to generalize about the demand for nuclear capacity on the basis of world average or regional average growth rates; each country must be assessed on an individual basis.

In any case, Table 13 shows that there is a reasonably large market available in countries that have relatively rapid electricity growth rates and also accept the principles of Canada's safeguards policy. Nonetheless, it should be kept in mind that the CANDU occupies only about 5 per cent of the world market for reactors, and that there will be a struggle for the sale of each unit. The size of the market alone should not be taken as an indication of the chances for success in penetrating it.

It appears that the best prospects for near term CANDU reactor sales will be concentrated in the rapidly industrializing economies. Thermal electrical generation in these countries is almost entirely oil-fired and nuclear is attractive both for future capacity and to displace oil.

Aside from expecting lower rates of demand growth, the larger industrialized countries are either committed to the LWR or to the development of their own reactor design. Many are experiencing problems with public acceptability.

Smaller industrial countries such as Australia, New Zealand, Denmark, Netherlands, Ireland, Portugal, Yugoslavia, and Greece may be potential markets. Some of these countries have been slow to commit to nuclear power and may require particular incentives to deviate from the mainstream LWR system. The Netherlands has a small LWR program, but has deferred further commitments for two years while a public debate is held. Yugoslavia has one American LWR under construction, but is taking a fresh look at different vendors and reactors, including the CANDU, before deciding on a reactor type for its new program. Romania already has committed itself to a multi-unit CANDU program, but has not placed any firm orders for NSSS components. Austrialia, with its abundant uranium, could be interested in the CANDU. Many of these smaller industrial countries are clearly desirable customers from both economic and non-proliferation perspectives.

Among the developing countries, the oil-exporters are in the best position to afford the capital investment in nuclear power. However, the human resources and technical infrastructure required to assimilate nuclear power are not always as well established as in the other advanced industrializing countries.

There are a number of newly industrializing developing countries such as South Korea which can use nuclear power to offset their dependence on imported oil. Others, like Argentina, Brazil and Mexico, have a variety of energy resources but view nuclear power as a legitimate and competitive component in their energy supply program. Some of the less wealthy, populous, predominantly agricultural countries such as India and China have an industrial sector which, although small in terms of their overall economy, is large enough in absolute size to accommodate a nuclear program.

Mexico is an important near term prospect. It has both the industrial infrastructure and the political commitment required for nuclear power autonomy. It has two LWRs under construction but, like Yugoslavia, is studying other vendors and reactor types, including the CANDU, before deciding on the reactor system or systems it will order for a program aimed at 20 GWe of capacity by the end of the century. Other oil exporters may also conclude, like Mexico, that their oil reserves are best used for purposes other than electricity generation and that nuclear power represents an investment of their oil reserves which will assist their technical development and provide a firm basis for future electrical supply.

In summary, the export market for nuclear reactors, and for the CANDU in particular, will develop slowly and erratically. Some countries which would otherwise be good prospects, such as

Argentina, Israel, China, and Pakistan, would have to agree to Canadian safeguards conditions before further sales could be made. There are, however, a large number of potential customers for whom full-scope safeguards are not a problem. Other countries may prove risky from economic and political perspectives.

There are near term possibilities for multi-unit sales in Romania and Mexico, and for further units in Korea. If AECL were to prove successful in these three markets simultaneously, the industry's immediate problems would be solved. Given the problems in obtaining sales outlined below, however, it is also possible that few and perhaps none of these sales will be made.

THE PRODUCT

The CANDU nuclear reactor is a technically proven system which, by the nature of its design and construction, offers a number of advantages for potential customers. Its use of natural uranium means that a country is more likely to be able to maintain a greater degree of autonomy in its nuclear power program than if it is dependent on foreign enrichment services.

Much of the technology associated with the CANDU, can be transferred to countries with relatively less developed industrial capacity. The eight large CANDU units in Ontario have accummulated a remarkable performance record for economy, safety, and reliability. Despite the capital costs (including the heavy water inventory), which may be slightly higher than those for LWRs, the CANDU is cost effective, especially in multi-unit stations, because of its lower fuelling cost and higher availability factors. It makes more efficient use of uranium on the once-through cycle than any other thermal reactor. It can also be modified to run on thorium, extending nuclear resources considerably.

Interviews conducted by a consultant in 1980 with a group of potential CANDU customers suggest that technological superiority is only one of a number of factors they may consider in selecting an eventual supplier. At least in the early stages of their considerations, importing countries tend to regard all competing reactor systems as being potentially equivalent in technological and economic terms once installed in their own system. They tend to give considerable importance to non-technological factors such as intergovernmental relations and the terms and conditions of sale (financing, technology transfer, etc.)

Clearly, Canada has a product which is capable of competing as a world class technology. Equally clearly, CANDU's technical characteristics alone cannot ensure successful export performance.

THE COMPETITION: STRUCTURE, PERFORMANCE AND MARKETING APPROACH

The worldwide reactor market is dominated by the LWR. The large industrial countries are virtually all committed to a nuclear program involving construction in the near term of LWRs, followed in the longer term by fast breeder reactors designed to use plutonium extracted from the spent fuel. Spent fuel reprocessing has thus been planned as an integral component of the light water fuel cycle from the inception of the program.

LWR technology, while basically a U.S. design, is now marketed by several different firms and countries – the U.S. (Westinghouse, General Electric, Combustion Engineering), France (Framatome), Sweden (ASEA-Atom), and Germany (KWU). The U.K. has produced its own reactor designs, but has recently opted in favour of a future commitment to a light water design. France, with the world's most ambitious nuclear program, is also a leader in the construction of breeder reactors. The unique feature of breeder reactors is their production of more fissile fuel than they consume. The resulting fuel can be recycled for use either in light water or fast breeder reactors, thus extending by several times the amount of energy which can be extracted from a given amount of uranium.

The CANDU fuel cycle is also capable of evolving into one which conserves and extends nuclear fuel resources. The thorium cycle, through recycling, represents an extension of nuclear fuel resources of the same order of magnitude as the fast breeder cycle. The thorium cycle's advantage, however, is its adaptability to the current CANDU technology with little modification.

By and large AECL's competitors share a number of common characteristics:

- most are large multinational companies with established reputations in the energy systems supply field, both nuclear and conventional, with a number of reactor units operating in a variety of different countries. They have high credibility as suppliers;
- several of the competitors are high-technology based manufacturers with an abundance of skills and resources. The proprietary rights for LWR technology generally rest with the manufacturing vendor, which emphasizes standardization and cost reduction to boost competitiveness; and uses R&D and engineering primarily to the extent that these contribute to the attainment of competitive goals;
- competitors tend to have broad and diversified product lines; most also provide non-nuclear generating capacity which allows economies of scale and spreading of commercial risks;
- they also tend to have worldwide networks of resident overseas offices permitting maintenance of a constant presence in prospective markets;
- some competitors (particularly France) have the advantage of a continuing strong domestic supply experience upon which to base overseas marketing efforts;
- some suppliers conduct existing utility business with prospective customers and have local manufacturing outlets which support localization objectives of prospective clients;
- most suppliers are capable of mounting broadly based industrial financing and trade packages commensurate with the size and scope of the reactor system proposals;
- major suppliers have excess production capacity and, therefore, foreign sales are eagerly sought;
- LWRs are marketed by several firms, providing customers with the advantage of choosing from a number of suppliers.

THE CANADIAN INDUSTRY: STRUCTURE, PERFORMANCE, AND MARKETING APPROACH

In contrast to foreign competitors, the Canadian nuclear industry grew up around a single customer, Ontario Hydro. The industrial structure included a large number of suppliers, generally at least two for each item of equipment to promote competition. Largely because there were no giant manufacturing companies in Canada which could supply the bulk of equipment for a nuclear station, the focus of the industry remained with the utility rather than moving into industry. Although there was an attempt to develop an industrial based export business in the late 1950's and early 1960's, the CANDU's technological excellence had not yet been demonstrated and Canada was not recognized as a high technology supplier. Whereas U.S. technology was accepted on faith in that era, Canada had to demonstrate clearly that its technology was world class. By the time the excellent performance of Ontario Hydro's Pickering station had been established, the industrial base was widely diffused. No one company with international marketing experience had a large enough share of the business to serve as a natural focus and so the marketing role fell to AECL.

AECL pursued the export market largely from its own base of expertise — research and engineering. It did not have the network of international distributors, worldwide contacts and export contracting experience which its competitors tended to have. It might still have had some selling success if the market for nuclear power had not collapsed to the extent it did as a result of the

international recession following the 1973/74 oil crisis. However with an oversupplied world market, marketing skills became critically important and Canada was not ready.

During the 1970's, as competition increased, Canadian industry and AECL attempted to develop more effective marketing methods, not always in a co-operative manner. As competition continued to build, the support which competing countries were receiving from their governments became more and more apparent, and by the end of the decade the Canadian government began to play a much more directly supporting role.

By the time the Mexican nuclear program was approaching the bidding stage during 1980 and particularly 1981, the Canadian marketing effort had pulled together significantly. AECL substantially expanded its marketing staff and, with the aid and cooperation of Canadian industry, launched a full scale marketing effort in Mexico, on a scale equivalent to that of its most serious competitors. The Canadian government supported the efforts through the full cooperation of its embassy and through several visits of senior Cabinet Ministers and by the Prime Minister to show Canada's interest in developing a much stronger relationship with Mexico over a range of trade, not limited to nuclear power.

With bids now submitted, industry and AECL are continuing their efforts in a closely cooperative program to demonstrate CANDU's strengths, and Canada's supporting industrial capability, to important groups of Mexicans.

Thus CANDU marketing efforts have evolved over a period of more than two decades, from an industrial based effort when there was no proven product to sell, through an AECL effort based largely on letting the proven technology sell itself, to the very recent era where industry, AECL, government and industry are working in a closely cooperative and coordinated way to market the CANDU reactor. Further evolution is likely, perhaps with industry's role growing further, and possibly with AECL's role diminishing to some extent. But such evolution would be aimed at streamlining Canada's marketing efforts; the important step of increasing the level of effort needed to participate in a serious way in a highly competitive world market has largely been achieved.

With this background, it is worth looking further at the structure of the Canadian nuclear industry from the point of view of its strengths and weaknesses in international competitions.

The extent to which the decentralized Canadian industrial base is an advantage or a problem varies to some degree from market to market. For example, it is beneficial in the sense that it is matched to the industrial structure of many industrializing countries. Such countries can see better possibilities for a transfer of technology from small Canadian firms to small firms in their own countries than from multinational giants. On the other hand, if a purchasing country chooses to buy each piece of equipment on an individual contract basis, as Romania is doing, it must deal with a large number of individual suppliers. This can require extensive and time consuming negotiations. Of course this problem can be surmounted by the purchaser giving one central contract to AECL, as Korea has done. This leaves AECL to deal with the individual companies but since AECL generally knows the suppliers from previous orders and because there are not the difficulties of differences in language, culture and business customs, the process is less onerous. Nonetheless there are problems remaining because the profits of the export reactor sale are split many ways and it is difficult to apportion the financial risks of the project appropriately, particularly for items such as penalty payments for project delays. Thus the federal government, through AECL, can end up taking a disproportionate share of project financial risk.

The choice of two or more suppliers for most components can also lead to difficulties with station standardization. For example, if, because of competitive bidding of suppliers, a different combination of suppliers of pipe hangers, control instrumentation and process system valves (to name only a few of many hundreds of components) is chosen for a new reactor, a very large amount of detailed engineering has to be redone entirely. This can be eliminated where several reactors are being built for one customer

(as in the case of Ontario Hydro building four-unit stations) or by choosing the same supplier for each. However the industry has not yet evolved to the point of establishing a small number of combinations of suppliers for each new station to permit more general standardization. It can be expected that efforts in this direction will occur in the not too distant future. If, because of limited sales, some suppliers drop out of the nuclear industry, leaving a single source for many components, a more standardized design may evolve with little effort.

In terms of marketing opportunities, the decentralized nature of the Canadian industry may lend itself to technology transfer to developing countries, but on the other hand it makes sales to industrialized countries more difficult. The large U.S. suppliers entered such markets primarily by licensing large local suppliers (such as Framatome in France and KWU in Germany). Their profits were made more from licensing fees than from equipment sales, but they were certainly able to establish their predominance in the world market. With a large number of small suppliers, this route would be much more difficult for Canada to follow. On the other hand, the competition for reactor sales in industrialized countries was over by the early 1970's. With the possibility of a few scattered exceptions, the main opportunities in the future are in the developing countries. Although Canada's industrial structure was clearly a liability in the competition for industrial markets, now lost, we should not be too quick to change it. It may well be the preferred structure for the competitions being entered now and for the near future.

ROLE OF GOVERNMENT

Introduction

Governments are extremely important actors in nuclear reactor sales. Even after they are in operation, reactors (of necessity) involve countries in a continuing long term relationship to ensure safe and efficient operation. In Canada, the federal government's role extends from financing nuclear research and development to developing the regulatory framework within which the industry operates, establishing safeguards requirements and determining the conditions under which nuclear cooperation with foreign countries may take place. Government commitment to the nuclear industry is, therefore, a crucial factor in determining success in export markets.

Safeguards

Canada's nonproliferation and safeguards policies provide the framework within which nuclear exports, whether of uranium or of nuclear equipment and technology, take place. Safeguards policies are intended to contribute to the achievement of Canada's broad foreign policy goals:

1. to promote the evolution of a more effective and comprehensive international nonproliferation regime;
2. to ensure that Canada's nuclear exports do not contribute to nuclear proliferation.

While the objectives of Canada's nonproliferation policy are non-commercial, the policy has been and will continue to be one of the myriad of technological, political, and economic factors which influence Canada's reactor export efforts. The purpose of this section is to describe briefly Canada's policy. A more detailed summary of those policies is found in Appendix 2.

The Early Safeguards Policy

Canada's safeguards policy has evolved over a period of some three decades. The first transfer of Canadian nuclear technology was to India in 1956 under the Columbo Plan. This was for a heavy water research reactor now called CIRUS. The agreement was made in the early days of the Atoms for Peace program when there was great hope for the benefits to the world of peaceful uses of nuclear power. Even so, the CIRUS reactor was covered by an early form of safeguards agreement between Canada

and India that the reactor would be used for peaceful purposes only. Subsequent sales of power reactors to Pakistan (1959) and India (1963 and 1966) were also covered by "peaceful purposes only" commitments and by agreements that Canadian technical experts could verify this undertaking. Subsequently, the safeguards verifications on these three power reactors were taken over by the International Atomic Energy Agency (IAEA), under agreements between the parties involved.

India set off a nuclear explosive in May 1974, using plutonium extracted from fuel irradiated in CIRUS. Although the fuel used was not itself supplied by Canada, and although India claimed the explosive device was not a bomb and that it was developed solely for peaceful purposes, it was clear that India had violated the intent of Canada's policy. As a result Canada announced a new safeguards policy which required much more extensive commitments from its nuclear trading partners. Neither India nor Pakistan were willing to accept the terms of Canada's 1974 policy, and all forms of nuclear cooperation with both countries were terminated. It should be noted, however, that the safeguards agreements which were in place on Canadian supplied power reactors remain in place and the IAEA continues to monitor them to verify that these reactors are not being used for the production of nuclear explosives. Although the early agreements do not allow IAEA inspectors the latitude that newer agreements provide, the Agency has been able to report that no unauthorized diversions have occurred to date. It is continuing to encourage Pakistan, in particular, to allow more comprehensive safeguards inspections.

The 1974 Policy

The key requirements of Canada's 1974 policy are that Canada's nuclear trading partners must commit to not use any Canadian supplied nuclear equipment, material or technology, or any nuclear material developed or processed with such Canadian supplied items, for any form of nuclear explosive. Further, such nuclear items must be covered by safeguards inspections for their lifetime. If IAEA inspections cease to be available for any reason, other means could be found but the inspections must continue. Canadian supplied nuclear items can be retransferred to a third country only if Canada agrees. Such agreement would be given, in practice, only where the third country had also accepted all of Canada's non-proliferation policy requirements. Canada also retains rights of prior consent before Canadian supplied fuel can be enriched beyond 20% (explosives cannot be made from lower levels of enrichment) or reprocessed to extract plutonium. The prior consent on reprocessing also applies to any source of fuel irradiated in Canadian supplied facilities. A commitment to adequate levels of physical protection over all Canadian supplied nuclear items is also required.

This 1974 policy is very broad and was seen as being too intrusive by some countries at the time. As mentioned earlier, India and Pakistan refused to accept it and nuclear cooperation was terminated in both cases. It has not been renewed.

Argentina had contracted to buy a 600 MWe CANDU in 1973. When the 1974 policy was announced Argentina agreed to accept it, after long negotiations, and the contract was allowed to continue. South Korea also agreed to accept the Canadian policy before it contracted for a CANDU-600 in 1976. Since that time many countries have signed bilateral agreements with Canada covering all of the elements of Canada's 1974 policy. All sales of Canadian uranium or other nuclear items continue to require that such bilateral agreements be in place. As more and more countries sit down at the negotiating table to see what it is that Canada really requires, the Canadian requirements are gaining more widespread acceptance.

Nuclear Supplier Group Guidelines

The major nuclear suppliers formed a Nuclear Supplier's Group (NSG) to consider safeguards requirements which they would all agree to apply, in an attempt to remove safeguards as an issue in

international sales competitions. The NSG guidelines were published in 1978; they are summarized in Appendix 2. Although they address many of the issues in Canada's 1974 policy, they do not go as far in some areas. Canada refused to reduce its standards and so some difference in bilateral requirements between supplying nations continues today.

The 1976 Policy

In 1976, Canada re-examined its safeguards policy, and decided to add one more important feature. That was that our nuclear trading partners (except for the five recognized nuclear weapons states*) must make a declaration to the international community that they would not develop nor acquire any nuclear explosive device, and that they would accept IAEA inspection of all of their nuclear facilities. Such an undertaking could be given by signing and ratifying the international Non-Proliferation Treaty (NPT). However Canada was prepared to accept an equivalent commitment to the international community.

The important point about this new element of policy was that it required that Canada's nuclear trading partners not only agree not to use Canadian supplied items to develop nuclear explosives, but that they commit to a total non-nuclear explosives undertaking.

The 1976 policy was not applied retroactively, but only to new sales or agreements. Most of the countries with which Canada would like to enter into nuclear cooperation have signed and ratified NPT. An important exception is Argentina. While Argentina has accepted IAEA safeguards on all nuclear facilities supplied by Canada or by other countries, it has reserved its right to develop a "peaceful nuclear explosive" at some future time if it so chooses, based on its indigenous technology. This is not allowed under Canada's "NPT or equivalent" policy; therefore Canada will not allow any new nuclear trade with Argentina. The only nuclear trade allowed is that for the completion of the CANDU-600 Cordoba reactor sold in 1974, and for items required to ensure the safe and reliable operation of this reactor.

Canadian Public Perception

Although it has been argued by some that Canada's non-proliferation policy is too strict and thus inhibits nuclear sales, it is probably more correct to say that it is a necessary basis to permit any Canadian nuclear export activity. The Canadian public has frequently made clear its concerns about nuclear proliferation which could result from Canadian sales of power reactors or uranium. With any less comprehensive non-proliferation policy, it seems entirely possible that the public would demand an end to all nuclear exports. In any case, with the possible exception of Argentina, it is not clear that any country with which Canada would currently consider entering into a nuclear cooperation agreement has rejected or would reject Canada for reasons of its non-proliferation policy.

On the other side of the argument, an even more restrictive policy, or a refusal of any nuclear exports, as urged by a small number of Canadians, would likely be counterproductive to an objective of a more stable world. For many developing countries a reliable and affordable energy supply is critical for economic and social stability. The energy source used in the recent past by so many countries to reach their current level of development — oil — no longer meets those criteria. Not all developing countries have the electricity demand nor technical infrastructure to accept nuclear power, but those that do will be able to use it to improve the lot of their people and remove some of the social disparities in the world which have in the past led to unrest and wars.

The NPT itself was formulated as a sort of international bargain. Countries which sign it agree to give up any right to nuclear explosives in exchange for a right of access to peaceful nuclear technology.

*The NPT recognizes as Nuclear Weapons States the U.S.A., U.S.S.R., U.K., France and China.

Thus it is a two-way agreement. To refuse to honour our part of the deal (to provide peaceful nuclear technology) would lead to more countries reserving the right to acquire nuclear explosives.

This argument does not require that Canada offer to sell to every country that seeks CANDU technology. Common sense has been applied to such requests in the past and will continue to be a fundamental element of Canadian nuclear non-proliferation policy in the future.

Political Exclusions: Taiwan

Canada's agreement to recognize the People's Republic of China effectively rules out nuclear co-operation between Canada and Taiwan. This has potential commercial implications. Taiwan is, after Korea, the world's second largest competitive market for reactors, with an aggressive nuclear program based on six American LWRs. It also purchased an experimental Canadian reactor in the early 1970's.

Financing

Reactor financing can be an extremely important factor in choosing between competing suppliers, especially for rapidly developing countries in which capital and foreign exchange are particularly scarce. It is in these markets that most prospective sales of CANDU are concentrated.

It is not possible to generalize about the priority which financing arrangements have in successful exporting. The importance of financing varies from case to case, depending upon the country and the resolution of other critical factors affecting the sale. In the Korean case, where safeguards, technology transfer, condition of contract and working relationships are essentially settled, financing is considered a key in achieving further reactor sales. In the Mexican case, where issues of technology choice, technology transfer, and localization of manufacture have not yet been resolved, financing may be third or fourth on the list of priority conditions. However, when these issues are resolved, competitive financing will inevitably become an important issue.

Export financing for Canadian reactor sales is provided by the Export Development Corporation, which acts in a commercial manner and, to the maximum extent possible, attempts to loan funds at rates which recover its costs of borrowing (but which do not, however, provide returns on government equity in EDC). On average, EDC rates tend to be three or four percentage points below market rates. However, recent changes in OECD consensus rates have been aimed at reducing this gap.

The competitiveness of a financing package cannot be assessed on the basis of face rates of interest alone, since face rates do not capture the effect of repayment-term length. This is one area in which EDC does offer terms more favourable than other countries. Face rates also do not take into account anticipated movements in currency values which ultimately help determine actual costs to the borrower.

Beyond interest rates is the question of availability of funds. EDC's ability to finance large projects is limited. EDC signings for all projects are expected to be about \$1.7 billion in 1981, growing at 15 per cent per annum thereafter. Based on the Korean model, if EDC were to commit about \$720 million for a reactor, each reactor would represent about one third of its annual signings. Given normal criteria of risk and project diversification, if several sales to Korea, Mexico and Romania were confirmed in all respects but finance, the EDC would be unable to accommodate them within its normal commercial framework.

To address these problems, a recent government decision requires that financing of large projects be considered on a case-by-base basis outside the normal commercial framework of the EDC. This is a useful mechanism which permits the government to weigh the benefits of a reactor sale against the costs of concessionary financing.

While concessional financing may be essential to winning export sales, there are clearly a number of drawbacks. First, depending upon terms and conditions negotiated for each individual loan, it may

be costly. Second, the indirect impact of concessional financing of one reactor on future nuclear and non-nuclear sales must be taken into account. Third, from the point of view of the vendor, the case-by-case funding process now being used does not give negotiating parties any assurance of funding cost or availability until the matter is presented for Cabinet consideration.

Government Support of Continued Research and Development

The federal government directly funds the research and development activities of AECL. Such R&D activities are important both to maintain a viable domestic industry and to support Canada's export activities.

A research and development capability is required to support the CANDU reactors which are already operating or committed in Canada and abroad. Even in a proven system, unexpected problems can occur. One of the main research activities of AECL is to provide continuing technological back-up to secure the CANDU system. This is essential not only for the smaller utilities which have bought CANDU's but also for Ontario Hydro.

Canada's situation as the unique supplier of the CANDU underlines the importance of this support for foreign customers. The 20 large CANDU units operating and under construction in Ontario, and the two others elsewhere in Canada, ensure that Canada's commitment to research and development in support of the CANDU system will continue.

A second major area for R&D is the future evolution of the CANDU system, primarily through the development of an advanced thorium fuel cycle. This is of interest to potential importers for two reasons. Firstly, countries which lack their own supplies of uranium clearly wish to improve their security of supply by developing fuel cycles, like the thorium cycle, which conserve uranium. Secondly, such future-oriented R&D ensures potential importers that they are choosing, in the CANDU, a technology which continues to evolve over time in a competitive environment.

Vigorous R&D programs to sustain and advance the CANDU system are of great value to Canada. They can be considered an important marketing tool for international sales as well as a symbol of continuing government support.

The Role of the AECB in Export Markets

The purchase of a Canadian plant by a foreign customer requires that the overseas regulatory agency develop a clear understanding of Canadian safety criteria and licensing precedents. This can be complicated because licensing philosophy and regulatory documentation vary from country to country. The practice in the U.S., for example, is to have extensive and detailed regulatory documents, and this practice is followed by users of LWR designs. In the U.K., regulatory documentation deals only with general principles and details are judged on a case-by-case basis. These judgments establish licensing precedents which are known only to those involved in the licensing process.

The Canadian approach lies somewhere between that of the U.S. and the U.K. The safety principles and criteria are documented along with more detailed requirements in areas such as safety systems and accident analyses. The advantage of this approach is that it places on the designer the responsibility to develop detailed designs which conform to the safety principles. This contrasts with the U.S. approach where the regulatory agency in effect specifies the design in much greater detail.

Thus, the regulatory approach of Canada's major competitors is quite legalistic, relying heavily on extensive documentation. The Canadian approach is more design-oriented and less extensively documented. While the Canadian approach is probably in the long run more effective in the regulatory sense, it can create difficulties for Canada's marketing effort abroad because the heavily documented approach is more easily transferable to foreign regulatory bodies. Essentially, the Canadian approach requires the transfer of expertise as well as documentation.

The AECB is attempting both to increase the documentation available on Canadian regulatory practices and to facilitate the transfer of expertise to foreign customers. To assist in this process, the Orientation Centre of the AECB provides training courses, arranges detachment of personnel, and conducts regular meetings and correspondence.

The AECB also supports the various IAEA programs for providing expert assistance to member countries. For example, the AECB has supplied two experts, for a total of 18 man-months, to assist the Korean Nuclear Regulatory Bureau with their safety evaluation of the Wolsung plant.

The Orientation Centre has participated in technical seminars or meetings with regulatory agencies where there is a prospect of a CANDU sale. The emphasis on these occasions has been to explain Canadian safety criteria. In the case of Greece, the interaction has ensured that the regulations to be adopted in that country will not be incompatible with Canadian licensing practices. In Korea and Romania this incompatibility already exists but is dealt with by granting exemptions from local regulations subject to conformity with Canadian practice.

The principal obstacle to verifying the licensability abroad is the difficulty of releasing appropriate documentation. There are various reasons why this situation arises. The overseas agency may have a legitimate safety reason to check documents which were not formally classified as licensing submissions in Canada, and are hence not available to them under the terms of the contract. In addition, licensing submissions prepared by utilities or their consultants are not automatically available to AECL for use overseas.

Many of these problems are being rectified by the movement to make more licensing information publicly available. Others can be alleviated by more rigorous identification of required licensing submissions (as is being pursued by AECL and AECB for the new 950 MWe design) and by agreement within the nuclear community to make available overseas all licensing submissions regardless of origin.

Summary: The Export Market

While Canada clearly possesses a world class nuclear technology, export markets will be uncertain and difficult to penetrate for at least the next decade. Competition is strong and other producers are also motivated by excess capacity in their domestic markets to pursue export prospects. In some areas, the competition is better organized, better funded, and more experienced than the Canadian industry.

On the other hand, the CANDU system does have some comparative advantages – principally its performance record and the autonomy and diversification of electricity supply it offers to prospective buyers. On balance, though, sales in the export market will continue to be difficult to realize.

Mexico and Korea are the most immediate prospects. Romania has recently agreed to terms for a two-unit sale. Other possibilities are concentrated in the latter half of the decade. Thus, even with significant changes in Canada's approach to reactor exports, it is possible that these other sales may come too late to have much impact on the commercial health of the nuclear industry during the critical period between now and the middle of the decade. Conversely, the sales in Korea and Mexico are extremely important to the industry.

5. THE VIABILITY OF THE CANADIAN NUCLEAR INDUSTRY INTO THE 1990's

Introduction

The review now turns to a key question: will the Canadian nuclear industry survive into the 1990's to build new reactors in addition to current domestic and foreign commitments?

The Scenarios

Both the domestic market and the export market are highly uncertain. Therefore, no single sales forecast can be selected as most likely for the 1980's. The approach taken here is to specify three sales scenarios ranging from quite pessimistic (scenarios 1 and 2) to moderately optimistic (scenario 3).

SCENARIO 1: No orders beyond current orders on hand, excluding Romania but including the Ontario Hydro retubing program. Despite the recent sale to Romania, this scenario is included for two reasons – first, it provides a base against which to measure the impact of sales (like Romania) on the industry; second, should the actual placing of orders for the Romanian sale be protracted for any reason, this scenario indicates the magnitude of the problems which delays would create for the industry.

SCENARIO 2: In addition to scenario 1, one reactor unit ordered in 1981; followed by 1 order in 1982; no further orders in the 1980's. This is essentially the present situation if Romania places firm orders in the near future.

SCENARIO 3: In addition to scenario 2, one reactor order in each year beginning in 1985.

Impact of Sales Scenarios on the Reactor Supply Industry

Reactor sales taken from each scenario are translated into orders for each firm in the sample of those interviewed by Woods Gordon. The level of business this implies for the firms is then compared to minimum levels required to stay in business. Where there are two suppliers, orders are allocated to each competitor on an alternating basis. The results of the analysis are summarized below for each scenario.

SCENARIO 1: As early as 1982, eight of the companies surveyed will be operating at levels of capacity utilization below those acceptable for maintenance of nuclear capabilities. As early as 1984, an additional six of the companies surveyed will be below acceptable levels with substantial unused capacity. As early as 1985, all but one of the suppliers surveyed (other than Ontario Hydro), will be operating at levels below those acceptable for maintenance of nuclear skills.

SCENARIO 2: Export orders in 1981 and 1982 will assist in maintaining utilization of capacity for most suppliers in the sample in the early 1980's but will not extend the horizon of work in progress much beyond that based on current orders on hand. This indicates that the Romanian sale, while certainly a boost to the industry, in no way resolves its underlying problems.

SCENARIO 3: Nuclear capabilities will be maintained in virtually all critical product categories but orders under this scenario will only be sufficient to support a single supplier among the same firms in any one product area.

The effects of order prospects under scenarios 1, 2 and 3 are illustrated in Figure 4 on p. 38, which shows the number of suppliers in the sample able to maintain nuclear capabilities over the 1980's. Figure 5 on p. 39 indicates the impact of the selected scenarios on CANDU-related employment in sample firms. Under all three scenarios there is a reduction in nuclear related business below current

levels. Under scenarios 1 and 2, however, all firms in the sample exit from the industry by the late 1980's.

The results of the sample survey can be generalized to the industry as a whole. Under both scenarios 1 and 2, the situation facing the industry in the 1980's is serious. Most suppliers will be faced in the near term with the decision of whether or not to stay in the nuclear industry. Under scenario 1 such decisions will probably face a number of companies in 1982; almost all companies by the end of 1983 or 1984. Under scenario 2 almost all companies will be faced with such a decision by 1985. Long lead times make the situation even more urgent. If orders are to be in the shops in time to alleviate forecast undercapacity, conclusion of additional domestic or export sales is required almost immediately.

One segment of the industry will, however, be assisted in remaining in the industry through participation in a proposed Ontario Hydro retubing program. Those suppliers expecting participation in this program anticipate a flow of manufacturing work starting as early as 1983 or 1984 and spread over a number of years. The impact of this work program will extend into the late 1980's, but the volume of work on a year-to-year basis is expected to be modest. On its own, work for the retubing program is likely to be below the minimum acceptable level for maintaining nuclear capabilities, unless work is placed or produced at a much quicker rate than requirements dictate.

One qualification needs to be noted. Decisions that firms make about continuing in the nuclear industry are not made automatically when capacity utilization falls below a predetermined level. Rather they are influenced by a number of commercial, strategic and psychological factors. At the present time most companies, with the possible exception of those most immediately affected by a lack of work, are delaying the decision facing them. Some feel optimistic about the long-term outlook for CANDU reactor sales: they foresee electrical load growth continuing in the 1990's and may attempt to remain in the industry until that time. In addition, many of the suppliers believe in the likelihood of some export sales in the 1980's. Some companies also expect to be assisted in surviving the 1980's by participation in work related to the proposed Ontario Hydro retubing program. However, the seriousness of the commercial prospects for the industry may well overrule non-economic considerations and the probability that Canada will lose its nuclear industry over the decade is significant.

Should suppliers decide to leave the nuclear industry, most critical for future industry capability would be the loss of experienced staff knowledgeable in nuclear design, nuclear product fabrication and testing, and nuclear project direction. Also important would be the loss of continuity in product development; loss of facilities both general and specialized, through conversion to other uses; and loss of capabilities in Canada as a result of possible transfer to foreign-based plants also involved in nuclear work.

These losses will be most critical in CANDU-specific product areas with no surviving key supplier: components such as the calandria vessel and fuel channels are related to the reactor assembly and fuelling systems and as such are not generally available on world markets. Loss of suppliers in any of these product areas will weaken both the total industry and Canada's ability to market CANDU in export markets as a physical product rather than as a reactor design.

In general, loss of nuclear business will not be a cause for any of the suppliers interviewed going out of business completely, with two exceptions. One is Canatom, whose organization is totally committed to the nuclear business in general, and to CANDU to a great degree. Another is Chase Nuclear, the only manufacturer of CANDU pressure tubes, whose operations in Canada were undertaken specifically for CANDU. Nevertheless, certain of the capabilities of these two firms could be maintained by their parent companies. Certain others will also be threatened but are likely to survive through diversification into other markets; several of these companies have already identified new business opportunities.

Conclusions for the Reactor Industry

The results of this section indicate that the situation for the reactor industry is serious. Only under scenario 3 would a significant proportion of suppliers be able to maintain their nuclear capabilities into the 1990's but even here the industry will eventually move from a two-supplier to a one-supplier industry. This rationalization of the industry appears inevitable.

To grasp fully the industry's problems, it is essential to understand the lead times involved in planning for nuclear power. It takes about ten years from the time a decision is taken to build a particular plant until the plant is actually in service delivering electricity. If an approved site exists, and a standardized reactor design is selected, the time can be eight years, or even less. If a new site must be selected and a new system designed, the time can be twelve years or more. Thus decisions on required capacity must be made about a decade ahead of the time they are needed.

Since planning must be done ten years ahead, utilities will have already committed and ordered the reactors they will need by about 1990. In fact, because growth rates have continued to decline, many utilities will have more capacity on line in 1990 than they now think they will need. Thus, the orders for reactors needed in the early 1990's which should normally be coming in now, are being delayed. Demand for the middle-and-late 1990's may not produce new orders until the middle of the 1980's.

The four CANDU reactors being built outside Ontario will be commissioned within a year or two, and almost all the manufacturing required for them in Canada has been completed. The eight reactor units for the second stages of the Pickering and Bruce stations will be finished in the mid-1980's, and manufacturing for them will also be complete within a few years. Only the four units for the Darlington station will keep manufacturers at work beyond the middle of the decade, but by no means at full capacity.

Timing is critical. The dates of new reactor unit orders in scenarios 2 and 3 are for placement of orders for equipment or services associated with a new reactor project. Thus, in a sense, scenarios 2 and 3 are already out of date. However, they still make clear the urgency of near term commitments to reactor orders if the industry is to survive.

Since domestic orders in the next few years are rather unlikely apart from Lepreau 2, for something like scenario 3 to be realized discussions with Mexico and Korea would have to be concluded without delay. Further commitments for export orders in 1983 or 1984 would also be required. Alternatively, a virtually immediate announcement of a commitment to build new domestic stations would be required.

Groundwork for export sales which will result in equipment orders over the 1985 to 1990 period must be put in place today. In the case of domestic stations (with the exception of twinning existing stations), the need for preliminary work including environmental assessment studies means that it is very late for announcement of new stations to be built in Canada if these are to result in equipment orders beginning in 1985.

In summary, the industry faces severe problems and the time available in which to act is short.

Heavy Water Industry Prospects

Producers of heavy water in Canada face a set of problems similar to those of the rest of the nuclear industry. These problems stem from the failure of firm new domestic and international markets for the CANDU system to materialize. In addition, the heavy water industry has some unique characteristics

FIGURE 4

MANUFACTURERS REMAINING IN NUCLEAR INDUSTRY

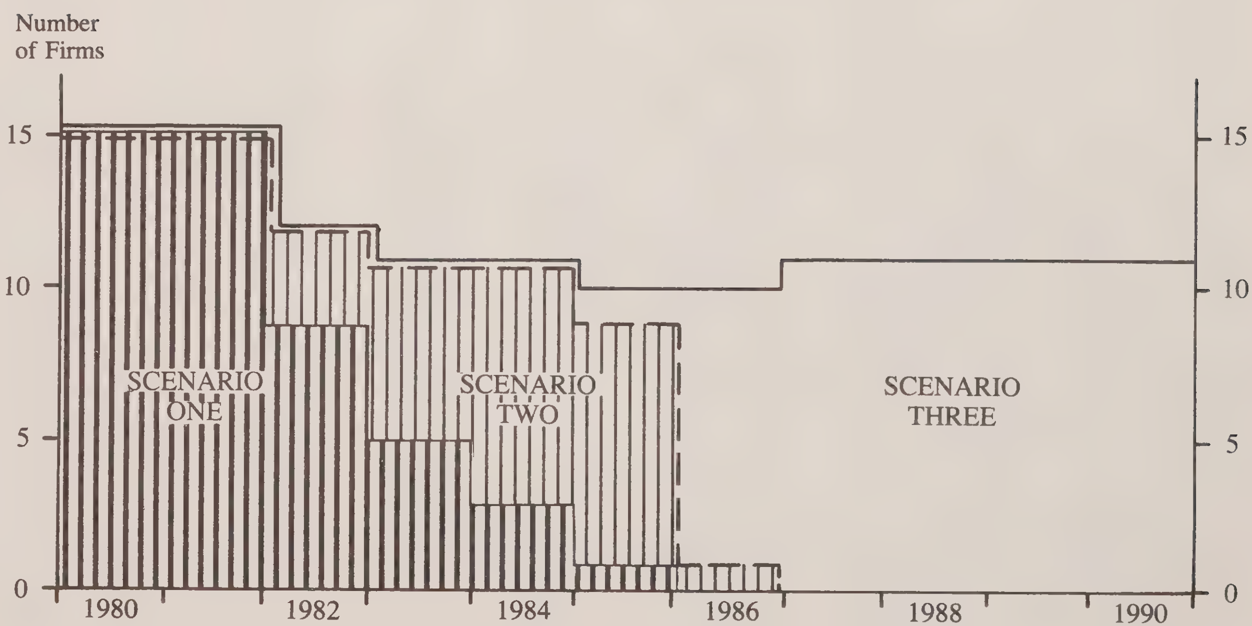
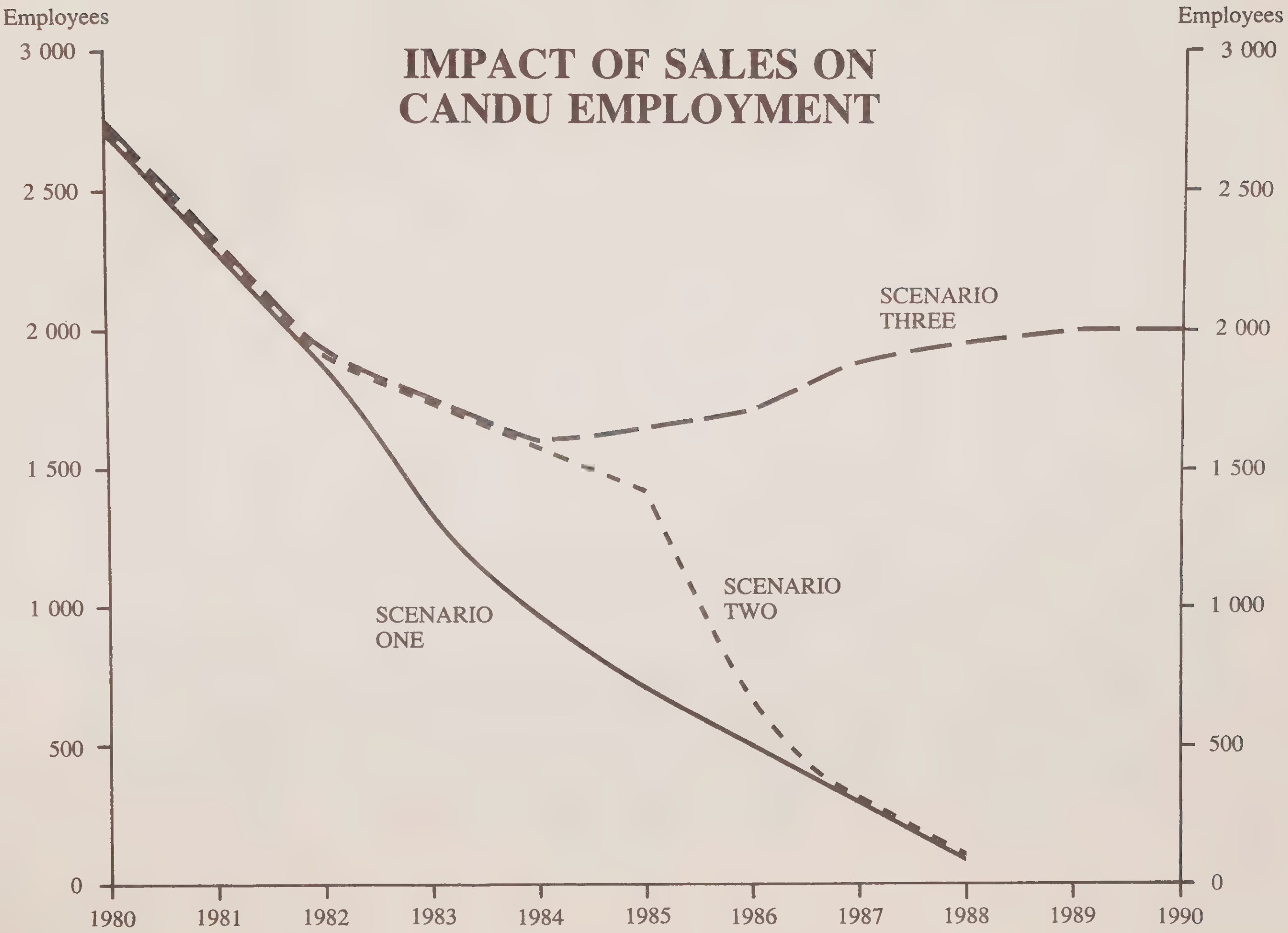


FIGURE 5

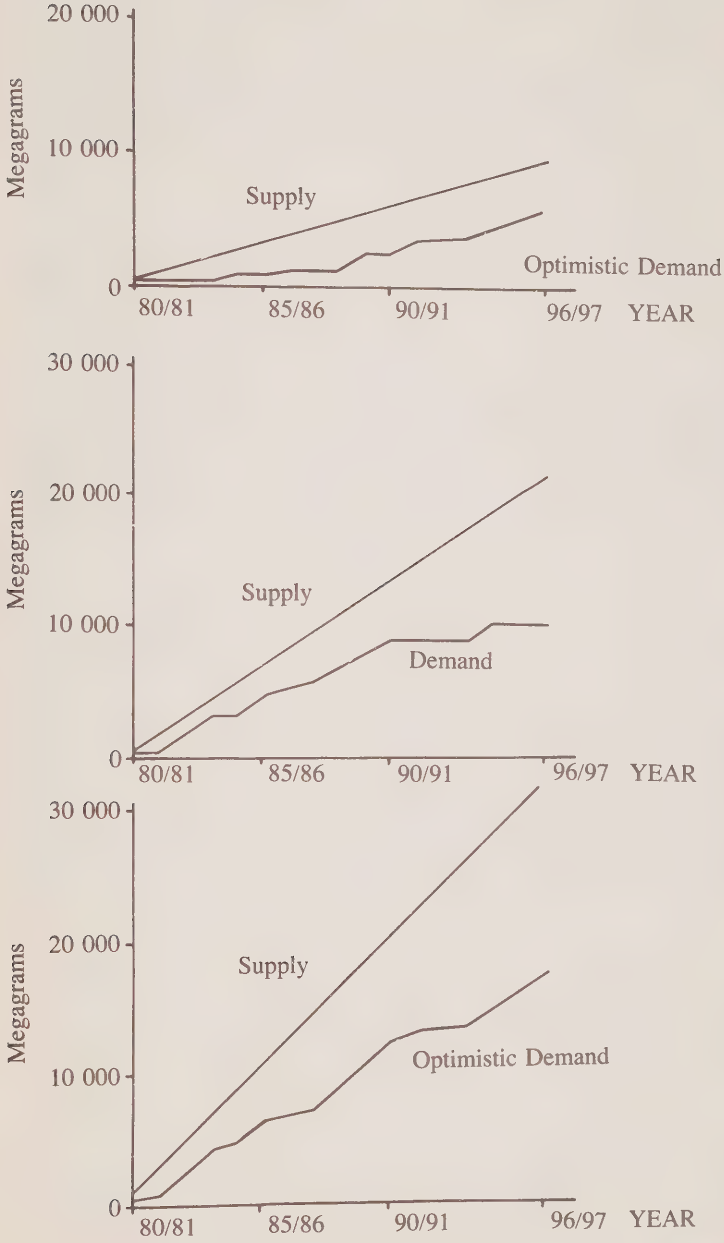

IMPACT OF SALES ON
CANDU EMPLOYMENT
Employees
3 000
2 500
2 000
1 500
1 000
500
0
Employees
3 000
2 500
2 000
1 500
1 000
500
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
SCENARIO
THREE
SCENARIO
TWO
SCENARIO
ONE

which cause its excess capacity problems to be somewhat more serious than those facing component manufacturers:

1) a significant fraction of the industry is located in an economically depressed region of the country (AECL's plants at Glace Bay and Port Hawkesbury in Nova Scotia). Therefore, heavy water production problems may have significant regional economic impacts;
2) the direct connection between a reactor sale and heavy water delivery is weakening as potential CANDU customers increasingly prefer to develop their own capability to produce heavy water. One of the producers of heavy water, the AECL Chemical Company (AECL-CC), is attempting to take advantage of this trend by marketing the technology to produce heavy water to countries interested in acquiring domestic supply security;
3) beyond the use of heavy water in several pharmaceutical processes and in quantities too small to draw down inventories appreciably, there are virtually no markets for heavy water other than CANDU reactors;
4) unlike most other suppliers of components in the nuclear industry who are able to adapt productive capacity to the production of output for other markets (for example, valves, piping and tubing which can be adapted to non-reactor uses), producers of heavy water cannot adapt their plant to produce anything but heavy water;
5) technically, heavy water plants are not easily adaptable to minimize accumulation of inventories and thereby avoid substantial inventory carrying costs. Plant output can only be marginally reduced without losing 'process integrity'; in other words, there exists a very limited potential to turn these plants down without turning them off;
6) sales of heavy water do not involve the continuous turnover of small quantities, but large blocks of 500 Mg (an entire year's output from AECL plants) or more. This fact, combined with the long lead times required for production planning in the heavy water industry creates a need to maintain inventories in amounts greater than those common in other industries. As a consequence, the normal carrying cost of heavy water inventories in large relative to those borne by other suppliers of components to the CANDU system;
7) Ontario Hydro and AECL heavy water plants have very different production cost structures. The capital cost of the older AECL plants has now been written off. The Ontario Hydro plants, and particularly the new Bruce B plant, still carry large capital charges. On the other hand, the AECL plants are supplied with steam from expensive coal-fired and oil-fired generating stations. Ontario Hydro obtains its steam from nuclear plants at Bruce at a very low incremental cost provided the steam is not needed for electricity generation. With expansions and modifications planned at Bruce by the mid-1980's surplus steam is expected to be available virtually all of the time. Thus the incremental operating cost of the Bruce plants will be much lower than those of the AECL plants;
8) unlike the situation of other suppliers, the market facing each producer of heavy water has evolved into well-defined shares: Ontario Hydro supplies the Ontario market and AECL-CC has become the sole supplier of heavy water both to the domestic non-Ontario market and to the offshore market;
9) the total supply of heavy water in Canada is not yet in a state of substantial surplus. Domestic reactor commissioning requirements and offshore needs for normal makeup quantities of heavy water are met. Even under the relatively optimistic demand scenarios presented here (see Figure 6) significant inventories accumulate by 1984/85. Such inventories accumulate only if both producers continue to operate at full capacity.

FIGURE 6

HEAVY WATER: CUMULATIVE SURPLUSES



AECL-CC
CUMULATIVE SURPLUS
(Scenario 3)

1980/81 78 Mg (makeup)
1985/86 4 reactor loads
1990/91 6 reactor loads
1996/97 6 reactor loads

ONTARIO HYDRO
CUMULATIVE SURPLUS

1980/81 1 reactor load
1985/86 4 reactor loads
1990/91 9 reactor loads
1996/97 22 reactor loads

TOTAL
CUMULATIVE SURPLUS

1980/81 1 reactor load
1985/86 8 reactor loads
1990/91 15 reactor loads
1996/97 28 reactor loads

6. SYNOPSIS

The previous sections have attempted to establish the central theses of this review;

- given reasonable assumptions about rates of growth of GNP, changes in energy prices, and other important factors (population growth, for example), consumption of electricity will continue to grow for the rest of the century but at rates which will likely remain well below historical averages.
- many utilities (e.g. Ontario Hydro) currently have some excess capacity. However, a comparison of demand forecasts with existing and committed capacity indicates that significant additions to capacity will be required to meet load growth in all parts of Canada in the 1990's.
- options for meeting projected load growth will be limited to coal, hydro, and nuclear. Given the increasing costs of coal and hydro – in both economic and environmental terms – CANDU reactors are an attractive option for meeting load growth, particularly east of Manitoba. There is, therefore, a good economic argument for maintaining the nuclear option to the 1990's.
- The situation over the next few years, however, may threaten the maintenance of the option. Given excess capacity being experienced by key utilities (e.g. Ontario), and reduced forecast rates of electrical demand growth in most of the provinces which have a nuclear program, domestic orders in the 1980's will be limited. The gap left by the absence of domestic orders might be filled by export sales, but competition in the export market is fierce. Mexico and Korea are the best near term prospects, but are by no means assured. The recent Romania sale helps, but many underlying problems will remain, particularly if the placing of orders is delayed for any reason. Other prospects are concentrated late in the decade, too late to provide immediate relief to the industry, and are in any case highly uncertain. Overall, the 1980's will be a very difficult decade for the reactor supply and heavy water industries.
- The commercial outlook for the 1980's may cause severe disruption within the Canadian nuclear industry. If actual sales performance coincides with one of the more cautious scenarios, all firms surveyed, and by implication virtually all firms in the industry, will be without nuclear business by 1985-86.
- Even the most optimistic scenario as defined in this paper indicates that the current structure of the industry cannot be maintained in the 1990's. Only one supplier of each component will remain in the nuclear business.

The rest of the review sets out specific policy options which could be pursued in response to the situation outlined above. Section 7 discusses options for the domestic reactor market; Section 8, the possibility of dedicated exports of electricity to U.S. markets; Section 9, options for the reactor export market and Section 10, the option of taking a laissez-faire approach.

7. POLICY OPTIONS FOR THE DOMESTIC MARKET

Introduction

The underlying determinant of the size of the domestic market for nuclear reactors is the rate of growth of electricity demand. One general option, therefore, is to promote the rate of growth of electricity demand over and above levels determined by present market conditions, through use of

subsidies and other government policies. Not only would this increase the demand for reactors, and increase capacity utilization in the industry, it would also, in some regions and sectors, substitute indigenous Canadian resources for costly and insecure imported energy.

There are obstacles to pursuing such a policy. First, the scope for increasing electricity demand growth over currently anticipated levels is limited by technical and economic factors. Forecasts show that the influence of market factors alone will cause the rate of growth of electricity to exceed growth rates of other forms of energy for the rest of the century. Thus electricity substitution is already largely internalized in the demand forecasts. Substitutions beyond these levels are of course possible but are limited by end-use technologies. For example, electricity is not yet feasible as an energy source for private transport. Secondly, acceleration of electricity growth on a nationwide basis would be a rather blunt instrument to increase the demand for nuclear power in Ontario, Quebec, and the Maritimes. Nonetheless, accelerated electricity substitution is a legitimate objective of government policy, both federal and provincial, but is not reflected in this analysis.

There are other factors with a direct bearing on the demand for nuclear power which the federal government can influence in a positive way.

Options to Improve Public Acceptability

Problems of public acceptability have made some utilities increasingly reluctant to pursue the nuclear option. Major public concerns include the long term management of radioactive wastes, the safety of reactor operation and the possible impacts of nuclear energy on human health and the natural environment. It is clear that the most important policy priority here is to ensure that these problems are being adequately addressed. It is also important that these problems be seen in the context of the benefits derived by Canada from its nuclear activities and in comparison with similar risks and benefits from other energy and industrial activities.

A good example of possible positive action is in the area of radioactive waste management, which public opinion polls indicate is an important factor in public opposition to further nuclear expansion. It is also one of the areas in which public perceptions differ most sharply from the views of scientists and engineers to whom the waste disposal problem appears more easily amenable to solution than a large number of non-nuclear related environmental and safety problems.

The federal and Ontario governments, through AECL and Ontario Hydro, have an active research and development program on the permanent disposal of spent fuel wastes. In the meantime, Ontario Hydro and the other nuclear utilities can store the irradiated nuclear fuel cheaply and safely at reactor sites for several decades. This will allow ample time for a research and development (R&D) program to study thoroughly the most appropriate methods for ultimate disposal of the wastes. The joint federal/Ontario R&D program, managed by AECL, has been underway for some years. Funding for the program was recently increased to a level of $30 million dollars per year.

This program is evaluating the feasibility of the concept of geological disposal in the stable rock formations of the Canadian Shield. Test drilling will be carried out to study fracture formations and water flow patterns deep underground. No wastes will be placed and no site selected for a repository until the concept has been found to be acceptably safe by the regulatory authorities and by governments. The evaluation of the concept may take up to ten years. Preliminary results from the program indicate that the maximum additional exposure to any individual from the repository would be a small fraction of the natural background radiation which everyone receives from natural sources. As the research program proceeds, and public understanding of the problem improves, it is expected that the public acceptability of radioactive waste management procedures will increase.

Improved Nuclear Incentives to the Provinces

Ontario, as one province with a substantial nuclear program, is politically committed to the nuclear option but has an excess generating capacity and a sluggish outlook for electrical demand growth. There are, however, good prospects for firm electricity exports from Ontario to the United States. Federal initiatives could have a more direct impact on nuclear prospects in Quebec and New Brunswick.

The most important issue between the two levels of government is that of federal financial assistance. Current federal policy provides for financing at Crown corporation rates for 50 per cent of the estimated cost of the first nuclear unit in each province.

There are two problems with this policy. First, because the federal share is based on estimated as opposed to actual costs, and because most nuclear projects have experienced substantial cost overruns, the actual federal share has fallen well short of 50 per cent. This has proven to be a contentious issue in Quebec and New Brunswick. An agreement was reached recently with New Brunswick on increased federal assistance to the Point Lepreau 1 project. This settlement was based, at least in part, on the role of Point Lepreau 1 in displacing imported oil to produce electricity in New Brunswick.

Secondly, assistance is limited to the first commercial reactor built in each province or to a subsequent reactor participating in a regional grid. This significantly limits the effectiveness of the program. It is unlikely that any province without a nuclear program at present will be induced by such an incentive package to make a commitment to a reactor. In those areas where financial assistance might induce additional commitments – New Brunswick (Lepreau 2) and Quebec (Gentilly 3) – the reactors are excluded because they are the second units in a program, and are not covered by regional power sharing agreements as required by federal policy.

An effective policy could involve a comprehensive solution of all outstanding issues between both provinces and the federal government which would include firm commitments to Lepreau 2 and to Gentilly 3. Such a policy could involve:

- extension of financing to cover a larger share of the delivered cost of a reactor unit;
- extension of favourable financial treatment to the second reactor unit in each province;
- more favourable interest rates and repayment terms;
- consideration of federal equity participation in reactor projects as was the case with the first Pickering CANDU reactors in Ontario.
- consideration of federal guarantees which would encourage financing from the private sector.

This package would involve federal expenditures, the benefit of which would be increased sales and added momentum for the domestic nuclear program. A comprehensive federal/provincial agreement would also demonstrate to foreign customers a clear Canadian commitment to the nuclear option. A further benefit, although hard to quantify, would be the additional incentive to non-nuclear provinces to embark on a nuclear program.

In addition, some changes in the structure of the Canadian nuclear industry could be undertaken in the context of new domestic orders. These could include provisions for enhanced technological development in the committing provinces and possibly for new project management structures which could draw to the maximum on experience of other Canadian organizations. This could help build a strong base in this important field which in turn could find application in other domestic and export projects. AECL is in the process of establishing an enhanced presence in Quebec, and has announced that research work on advanced fuel cycles will be one of its priorities in that province.

Rationalization of Heavy Water Production

While the heavy water industry shares many of the problems of the reactor supply industry, its unique technical and economic characteristics make the situation even more critical.

As noted earlier, decreases in demand experienced throughout the industry are aggravated by the desire of potential CANDU customers to build their own heavy water plants. In addition, unlike the reactor supply industry, heavy water producers can produce only heavy water, which has no alternative markets. Finally, for technical reasons, plants must be run close to full capacity or not at all. Thus, it is difficult for heavy water production to adjust to decreases in demand. The stark alternatives are to accumulate costly inventories or to shut plants down. It is not clear, however, that a mothballed plant can ever be returned to production, so that closing a plant for an extended period may involve its total write-off.

There does not appear to be any plausible scenario in which the output of all Canada's heavy water plants will be required through the decade of the 1980's. AECL has already begun to accumulate inventories, and will continue until the inventory reaches a value of about 1 500 megagrams. If by that time, markets are not foreseeable for further production, AECL may begin phasing out its heavy water production.

Rationalization involves difficult decisions. On the one hand, Ontario Hydro's heavy water plants show significantly lower operating costs than Maritime plants and are large enough to supply the domestic and foreign markets by themselves. On the other hand, AECL's Maritime plants are an important source of income and employment in an economically depressed region. Closure of the plants would generate adverse socio-economic impacts. Further, closure of AECL's plants might affect Canada's ability to sell reactors abroad. Foreign customers might be reluctant to buy from a company unable to guarantee a supply of heavy water from inhouse sources.

In sum, heavy water poses difficult problems. Rationalization is clearly required, but aside from an improvement in economic efficiency, it is difficult to foresee any gains from a rationalization decision in terms of the problems facing the industry as a whole. It is, for example, difficult to argue that a rationalization decision will increase the chances of domestic or foreign sales. At best, it will leave them unchanged. At worst, it could have a significant adverse impact on AECL's ability to market CANDU in export markets.

Conclusions

While scope for policy action in the domestic market is limited, some positive steps are possible. The most promising options for improving the industry's prospects in the short run are policies aimed at achieving an early commitment by Québec and New Brunswick to Gentilly-3 and Lepreau 2 respectively. Discussions with Ontario about the possibility of new reactors committed at least partially to exports should also be undertaken shortly.

8. REACTORS FOR POWER EXPORT

Introduction

Building reactors for power export is an attractive option for a number of reasons. Potential profits are likely to be significant. In addition, such a program would increase throughput in the domestic nuclear industry at a time of excess capacity, earn substantial amounts of foreign exchange and be

consistent with established policies of maximum upgrading of Canadian resources (uranium) before export.

On the other hand, dedicated exports would create incremental risks in public acceptability. For any given site these risks are similar to those posed by the production of electricity for domestic use, but there is a heightened political sensitivity about incurring risks for exported power. Concerns over impacts on health, safety, and the natural environment incurred by electricity exports would have to be carefully addressed.

Aside from problems of public acceptability, establishing the feasibility and desirability of dedicated exports involves addressing some difficult issues. First, a market must exist for electricity exports in general. Second, CANDU reactors must be capable, in economic terms, of capturing a share of this market. Finally, there are complex institutional, regulatory and contractual hurdles to be overcome.

The Market

Firm export opportunities could arise for three reasons:

1) U.S. utilities which still rely on baseload oil-fired generation will have an incentive to import firm power from Canadian CANDU reactors, if imported energy is less expensive than burning oil. This is the oil dispacement market;
2) if because of regulatory delays, U.S. utilities are unable to put capacity in place in time to meet load growth, it leaves a gap between available capacity and the utilities' requirements. This is the capacity constrained market;
3) the possibility of pre-empting the construction of coal-fired generation in the U.S. Costs of energy from new coal-fired capacity are expected to be higher than the cost of energy from CANDU because of the increasing real price of coal and the high costs of environmental protection measures.

Empirical work undertaken by EMR has tentatively identified the potential size of each of these markets over the next 20 years. The results should be considered as suggestive only.

First, making a number of assumptions about the rate at which U.S. utilities will substitute other generation for oil-fired facilities, and the economics of generating and transmitting power from CANDU reactors, from 1989 to 2001 a potential "oil-displacement" market of several thousand megawatts of baseload capacity exists in the North-Eastern United States.

Second, an assessment of the overall size of the market for new capacity displaced was made. Here again, an opportunity appears to exist for a share of a market of several thousand megawatts of new baseload capacity in the decade of the 1990's.

The share of each market ultimately captured by exports from nuclear facilities will, of course depend on the nature and cost of alternatives facing potential importers: for example, imports from other U.S. utilities; hydro power from Québec; and demand reduction by electrical load management. However, as indicated earlier, nuclear energy is an economically attractive technology in the long term for baseload generation when compared to the available alternatives. Therefore, while a significant fraction of the export market could be captured in the short run by low cost hydro, a large and profitable market for exports from nuclear reactors can be projected in the decade of the 1990's and perhaps beyond.

However, both these displacement markets are likely to be of limited duration. Most utilities have a policy of substituting out of oil. For many, this policy is on hold pending the resolution of issues such as raising capital and the trends of oil prices in the 1980's, but they will eventually resolve these questions and remove that market. Export opportunities arising from U.S. capacity shortages may also

be relatively short-lived. Problems experienced with obtaining approval for additions to capacity will likely be resolved over the long term, as the economic and energy consequences of continued delay become apparent. For this reason, the export of CANDU-based electrical energy may be confined to an export window beginning in 1990 and lasting to 2000 or 2005. Preliminary analysis indicates that payback times are short enough to allow attractive profits from even these brief windows if acted upon quickly. Given lead times involved in reactor construction, this implies a decision must be made soon if Canada wishes to take advantage of this market. The third type of market for CANDU exports, displacement of coal-fired generation in the United States, is a longer term opportunity based on comparative costs of generation alternatives.

Options for Meeting Export Demands

There are two basic options for meeting export demands. The first option involves the construction of dedicated plants which would provide baseload power to U.S. utilities over a period encompassing the life of the facilities. The second involves prebuilding a number of CANDU units to supply American markets with baseload power in the initial years of operation but with the ultimate intention of repatriating the power to meet expected Canadian demand.

Dedicated electricity sales from a nuclear plant could be undertaken by an existing utility, or through the formation of a new corporation. In either case, this option would require negotiation of contracts, the establishment of a financial and management structure, and the construction of nuclear export facilities. Sites are available in the potential exporting provinces, and the design should be largely standardized. Given present conditions, the lead time might be about 10 years. Similar lead times, if not longer, would apply to new capacity in the United States which would compete with Canadian imports.

Prebuilding options would involve advancing the construction schedules of nuclear plants eventually needed to meet expected domestic load growth in Ontario and/or New Brunswick: the first post Darlington Station Lepreau 2. One advantage of this scheme is that lead times are significantly reduced, thereby taking full advantage of the forecast market window. The objective of a prebuilding scheme, from a utility's point of view, is to earn profits on sale of energy to the U.S. In the long run, domestic benefits will appear as lower rate structures for domestic consumers.

Conclusions

A preliminary economic and market analysis undertaken by EMR indicates that a large profitable market for electricity exports from Canada will develop in the U.S. over the next 20 years. Economic analysis suggests that exports from CANDU reactors would be capable of capturing a portion of this market. Constructing reactors for power export could, therefore, generate attractive economic returns and, in addition, provide badly needed business for the Canadian nuclear industry at a time of over-capacity. However, due to the high degree of uncertainty in any longer term forecast of markets and comparative costs, the risks of building generating capacity in Canada to take advantage of this potential export opportunity have to be weighed carefully in relation to the potential benefits that exports provide. These risks could be reduced by long term contracts with importing utilities. Because the market window is expected to start around 1990 and last only until soon after the turn of the century, and because of the long lead times for nuclear plan commissioning, delays in deciding whether to pursue this option will render the oil displacement and capacity constrained markets increasingly less likely as targets for an electricity export program.

Important non-economic risks are also involved, including institutional barriers and public perception of increased environmental and safety risks. Before any construction for export could take

place, American utilities and regulatory agencies would have to indicate, through contractual commitments and clear authorization for imports, their willingness to allow some utilities to become at least partially dependent on a Canadian supplier for a vital energy form. Further, transmission capacity is a factor of prime importance in any firm export proposal. The construction of increased transmission facilities from both sides of the border is a prerequisite to increased electricity exchanges between Canada and the United States. Because of strong environmental opposition to transmission lines, this could be a serious bottleneck.

9. POLICY OPTIONS FOR EXPORT MARKETS

Introduction

Section 4 discussed the key factors influencing export performance. The apparent technical superiority of CANDU seems to play a less significant role in a successful sales effort than conventional Canadian wisdom would indicate. In fact, Canada's emphasis in the past on technology has led to a perception of AECL as a research and product oriented company, which lacks commercial and project management skills.

There is a broad continuum of policy options available, ranging from relatively straightforward changes in administrative procedures to much more fundamental changes in financing or levels of subsidization. In addition, there are a range of non-technological factors which could be altered to enhance Canada's foreign sales prospects. Some, such as technology transfer, decentralization of the Canadian industry, and the credibility of Canada as a supplier can only be changed by the actions of the industry itself. Others (marketing, finance, countertrade) may involve co-ordinated action by the government, AECL, and private industry.

Costs, risks and benefits are in some cases high and difficult to define and quantify. Export of big ticket items such as reactors is inherently risky – financial losses can never be ruled out. The international market is highly competitive and sales prospects are very uncertain. While devoting more resources to international marketing or altering safeguard policies will not assure success, they will increase its probability although there is a risk that policies undertaken at some economic or political cost may generate no return. It should, however, be noted that a policy of doing nothing carries with it risks of its own.

Industry Restructuring to Promote Greater Success in the Export Market

Questions have been raised regarding the appropriateness of the structure of the Canadian nuclear industry for successful penetration of export markets.* There are a number of options the government on its own or as a key actor through AECL, might consider with respect to industry structure. In surveying the options for the evolution of industrial structure, there is a range of possibilities which may be grouped conveniently into three categories:

(i) the status quo;
(ii) the creation of a product-oriented manufacturing vendor as suggested in the SECOR report;
(iii) greater co-ordination of the individual actors.

*the SECOR Report.

i) The Status Quo:

The status quo does not mean that the industry remains static. Rather, it means that the industry will continue to evolve along the line determined by general commercial conditions, and by existing practices which have been developed within the industry. Commercial factors (low rates of ordering, excess capacity) will gradually transform the industry from a two-supplier system for major manufactured components to a one-supplier structure. Given the existing nature of the industry, this will likely occur by a process of natural attrition.

With exports, the industry will likely continue its efforts to increase co-operation. AECL, EDC, and the members of the Organization of Candu Industries (OCI) are all attempting to improve levels of co-operation in order to enhance their ability to respond to requests for bids, to manage projects and to reduce opportunities for exploitation by foreign customers which the decentralized nature of the industry has permitted in the past.

ii) Secor Report Suggestions:

The SECOR report argues that changes as suggested above are largely cosmetic and fail to address the real problem which prevents the Canadian nuclear industry from gaining an increased penetration of foreign markets: the central role of AECL with its orientation toward engineering/design and R&D rather than product manufacture and delivery. The report argues that the sine qua non of improved export sale performance is a fundamental change in industry structure which would involve the creation of a single large manufacturing vendor (probably private sector) using R&D, engineering and design to lower costs and increase market penetration only.

As envisioned by SECOR, such a firm would need to be assured of a significant proportion of the Canadian market, would require proprietary rights to the CANDU design now held by AECL, would be fully responsible for marketing abroad, and would have full control of CANDU nuclear power reactor projects and responsibility for manufacturing key components. Such a firm would adopt a multi-national corporate type strategy to secure 20 per cent of the world power reactor market.

While some additional structural change may still be required in the Canadian nuclear industry, such a fundamental restructuring poses a number of problems. Since it is not clear what role structural problems (as opposed to other problems) have played in Canada's export difficulties to date, there is a real possiblity that such a fundamental change would do little to improve export markets while running the risk of impairing a structure which has shown itself to be extremely successful in the major domestic market (Ontario). This is particularly important because under most conceivable sets of circumstances the domestic market will remain the raison d'être of the Canadian nuclear industry. Also, while the decentralized structure may make penetration of industrialized markets difficult, it may well be a preferred structure for marketing in developing countries which constitute most near term opportunities.

Other practical problems would also be involved: who would have the competence and authority to implement this concept? Could any agreement be achieved among AECL, OCI, and Ontario Hydro as to what – if any – their new roles would be? Would the new manufacturing/vendor have international credibility without a strong base of domestic business?

iii) Greater Co-ordination:

An alternative to the manufacturing-vendor concept is more vigorous and higher level co-operation which would improve the industry's ability to compete abroad while maintaining the structure it has successfully evolved for the domestic market. This option might entail the creation of a high level Nuclear Co-operation Committee which would establish directions, determine areas for improved co-operation, and establish mechanisms for bringing necessary change about. Such a committee would consist of AECL, the federal government, the provincial government(s), the utility(ies) and private industry representatives. It would essentially be an expanded OCI with the ability to make important decisions.

Again the major problems would be legal and operational. How would such a committee be structured? Would the industry co-operate? How could decisions be enforced? All these issues would present real problems – offset, however, by the real benefits improved co-operation and co-ordination would offer for greater foreign sales.

Marketing

Canadian marketing efforts in the past have been inadequate. In part this is a consequence of Canada's small size in relation to its competitors. In part, however, it has been caused by lack of a coherent market strategy; a failure to identify key contacts; an apparent inability to deliver adequate amounts of information to decision makers on time; and an approach that emphasized the technological superiority of the CANDU system while paying insufficient attention to the key non-technological factors. The role of government in restricting AECL's activities in some markets is also a factor.

AECL and the nuclear industry have now moved to correct some of these problems, to the extent that they are within their areas of influence. Creation of AECL International is part of a corporate effort to improve its marketing strategy and practices. Closer co-operation in marketing efforts between AECL and the OCI, as in the recent Mexican bid is reducing problems associated with decentralization of the Canadian industry.

Important decisions are still required. A broad sustained marketing effort is costly. One policy option, then, is to increase AECL's marketing activities, which might involve some government funding. The drawback here is that, given soft export markets and intense competition, there is no guarantee of success. Increased activity will increase the probability of a sale, but the possibility of no return at all remains real.

Safeguards

Although it has been argued by some that Canada's safeguards policy is so restrictive as to impede nuclear reactor sales, closer examination shows that this case is not very strong. With the possible exception of a second sale to Argentina, it is difficult to demonstrate that sales have been lost due to Canada's safeguards requirements. As more and more countries sign bilateral agreements with Canada, our non-poliferation policy is becoming more widely understood and accepted.

On the other side of the issue, without a policy which requires our nuclear trading partners to undertake a strong and binding commitment not to acquire nuclear explosives, it is likely that the Canadian public would demand the termination of all nuclear exports.

It is concluded from these considerations that significant modications to nuclear safeguards policy should not be considered as an option.

Political Exclusions

Current Canadian government policy precludes nuclear co-operation with a number of countries; the most important from a marketing point of view being Taiwan. This affects the size of the reactor market open to AECL. Other exclusions – for example, the U.S. military program – primarily affect the size of AECL's heavy water market.

One policy option, therefore, is to modify Canada's exclusion policies. Nuclear co-operation between Canada and Taiwan would require a bilateral safeguard agreement between governments, as well as involvement of both AECL and the EDC. However, Canada's 1970 recognition of the People's Republic of China rules out government relations between Canada and Taiwan, including transactions carried out by Crown corporations.

Financing

Financing is another area in which Canada is at best just competitive with some of the alternative suppliers. The EDC, which undertakes reactor financing, views itself as a commercial entity which provides funds on conditions which cover its own costs of borrowing. Concessional interest rates are partly counterbalanced by the service charges which EDC imposes on AECL. This limits the extent to which AECL can compete with countries which provide concessional financing as an overall export promotion policy. Further, given the size of EDC's annual signings, the scope for handling an increase in reactor sales is limited.

Changes have recently been approved in export financing policy. New provisions allow case by case consideration by Cabinet of major project financing which exceeds EDC's normal capability. While this improves prospects, it does not guarantee availability, which may impose a constraint on negotiating export contracts.

Further improvement in financial assistance is a policy option open to the federal government. This could include for example, a guarantee of financing at concessional rates for foreign sales.

This policy has a number of advantages. It would improve immediate sales prospects in key markets: Korea and Mexico. These are sales which are critical to the industry at a time of overcapacity. It also involves no dramatic change in Canadian policy, but merely an improvement in terms and conditions consistent with an overall policy of promoting Canadian exports.

The main drawback is expense. EDC estimates that a 1 per cent reduction in interest rates is equivalent to roughly a $30 million reduction in selling price. While the costs of concessional financing are large, such expenses are only incurred if sales are successfully concluded. With policies such as an increased marketing effort, expenses are incurred regardless of the ultimate effect on sales.

Conclusions

There are a number of policy options available to the government which might improve Canada's performance in foreign markets. These vary widely in terms of degree of difficulty, cost, and potential benefits. At the simplest level AECL could be allowed more commercial freedom to pursue export sales. While this option has few costs in financial or public acceptability terms, it is unlikely to improve sales prospects in any significant way. Another option is to improve terms under which reactor sales are financed. This is an attractive option in the sense that costs of concessional financing are only incurred if a sale is concluded with the economic benefits that a sale generates. On the other hand, the implicit subsidies involved in concessional financing are high and would have to be financed by appropriations from the Consolidated Revenue Fund. Finally, strong government commitment has a positive effect on sales prospects at little cost.

In sum, export markets are soft and the competition fierce. Policies which would significantly improve Canadian sales performance involve some costs. Even with strong policy action, there is no assurance of success – the probabilities of success are simply improved. The government then is faced with a difficult decision – to take a course of action which is potentially costly, the outcome of which is uncertain, but which potentially generates significant benefits for the nuclear industry and the economy as a whole; or to accept the consequences for Canada of taking no action at all.

10. A LAISSEZ-FAIRE POLICY:

A laissez-faire option avoids the economic, financial and public acceptability costs of an active policy.

Previous sections have made it clear that there are no easy solutions to the industry's problems. Policy options to improve the domestic outlook for the industry are limited. A dedicated exports option is attractive in many respects, but may be constrained by institutional factors and involve high public acceptability costs. The export market is weak and very competitive – big improvements in the outlook for reactor exports would require tough decisions on political exclusions, financing and marketing, and perhaps the pricing of heavy water, with no guarantee of success. A real possibility exists that policies which are costly in both economic and public acceptability terms would produce little improvement in the industry's prospects. A laissez-faire policy avoids these risks.

Against these avoided costs, the consequences of a laissez-faire option for the domestic nuclear industry and the maintenance of the nuclear option must be weighed. There is a risk that large segments of the nuclear industry could be dismantled in the latter half of the 1980's. If load growth continued in the 1990's, this implies that (1) Canada would simply have to do without nuclear power, (2) nuclear technology would have to be imported from abroad or, (3) the Canadian industry would have to be reassembled.

1) *Doing without CANDU technology:* The alternatives to the CANDU as an electricity source are hydro, coal, and imported nuclear systems. In Eastern Canada, the available economic hydro sites will largely be developed by the end of the century. In Ontario, there are virtually no large economic hydro sites left even now. Nuclear power is already cheaper than coal in this region and its economic advantage will increase. The non-nuclear option would thus include higher electrical generation costs, as well as lost industrial and technological benefits.

2) *Importing Technology from Abroad:* Because the design and the content of the CANDU is Canadian, it offers industrial benefits that an imported reactor could not match. It provides desirable highly skilled employment. It represents a stimulus to a wide range of research, development, and other high-technology activities in Canada: instrumentation, quality assurance, design engineering, etc. If imported reactors were used in Canada, these activities would be carried out in the vendor countries' laboratories and workshops, and many of the industrial and trade benefits would be lost, along with a certain degree of energy security.

   In return, Canada would have the advantages of adopting a reactor system used all over the world, competitive sourcing, and benefits of widely shared experience. However, since the CANDU already performs better than the LWR, it is unlikely that these benefits would compensate for the advantages Canada would lose by being a consumer rather than an innovator.

3) *Exit and Reassembly:* The industrial capacity which may be lost over the next few years could, in principle, be revived if demand for CANDU units increases at a later date. Ontario Hydro's nuclear program would continue, the designs would still exist. This scenario is possible, but it overlooks several factors. Even if designs exist on paper, advanced technology depends on the skill and motivation of highly trained people working in teams. The skills to design and build complex equipment like the CANDU fuelling machine are acquired over many years. Once the teams are dispersed and people have involved themselves in other activities, it is hard to put them back together. New teams must be assembled and new people trained. Also both people and companies would have to be motivated to return to an activity which has foundered once before. It would be hard to re-establish the confidence necessary to rebuild an industry which had been allowed to lapse. In addition, technology does not stand still; other reactor designers and builders

in the world will be working steadily through the early part of this decade, gaining experience, improving their design and procedures, and establishing consumer confidence.

Again, these are prospects to which a degree of uncertainty is attached. The sales scenarios used in this paper are simply possibilities. If things went unexpectedly well for the industry, it is always possible that no commercial problems would occur, even in the absence of an active policy.

In summary, a laissez-faire policy would avoid the costs inevitably involved in taking positive action with respect to the nuclear industry. It would, however, also involve costs of adjustment. More generally, however, a laissez-faire policy also involves foregoing the benefits an active policy would generate. The next chapter attempts to quantify these economic and industrial costs and benefits.

11. AN OVERVIEW OF ECONOMIC AND FINANCIAL IMPLICATIONS

The Economic Benefits of the CANDU Option

Perhaps the easiest way to illustrate the benefits arising from sustaining the CANDU nuclear option is to discuss the costs which would be imposed on the Canadian economy by the three laissez-faire scenarios which were introduced in Chapter 10.

DOING WITHOUT CANDU

As pointed out above, the alternatives to the CANDU as an electricity source are hydro, coal, and imported nuclear systems.

According to the latest Ontario Hydro analysis for stations coming into service in 1995, the capital costs of coal-fired capacity has increased to the point (in dollars per kilowatt) that they are roughly comparable with nuclear costs.* Therefore, the economic comparison is approximately the present value of the difference in the cost of operating each type of plant over its lifetime. For coal imported into Ontario from the U.S., the differences is approximately 40 mills per kWh; for Canadian coal delivered in Ontario approximately 75 mills per kWh. The present worth of these differences is shown (Table 14) for two real discount rates. The 3 per cent rate represents the utility's long-term discount rate. The 7.5 per cent is EMR's estimate of the social rate of discount.

IMPORTING LWRs FROM ABROAD

CANDU reactors, of course, are not the only alternative to costly coal and hydro. Imported LWRs would also use Canada's abundant uranium and, in principle, offer some of the same advantages as the CANDU reactor.

Ontario Hydro's estimates indicate that the capital charges of LWRs are fairly close to those of CANDU, adjusted for CANDU's superior capacity factor. Again, therefore, the economic advantage of CANDU vs LWR comes down to the present value of the difference in operating costs over the

*On the one hand, coal costs have increased to reflect the cost of flue gas desulphurization (estimated at $272/kW in $1995). On the other hand, nuclear costs have been reduced to reflect excess capacity in Ontario Hydro's heavy water plants. Because of the latter, the calculations are, precisely speaking, valid only for Ontario. They are, however, representative of the value of CANDU to other areas of Canada which face similarly high coal costs.

TABLE 14

PRESENT VALUE OF SAVINGS IN OPERATING COSTS: NUCLEAR OVER COAL $1981 per 850 MWe unit

	3%	7.5%
U.S. Coal	1.6 billion	1.0 billion
Canadian Coal	3.0 billion	1.8 billion

reactor's lifetime. This amounts to 3 mills/kWh in Ontario Hydro's high average capacity factor case. The present value of this difference in favour of CANDU in $1981 is $385 million per 850 MWe unit discounted at 3 per cent and $232 million per 850 MWe unit discounted at 7.5 per cent. This estimate, however, ignores important costs such as the start-up costs of a new technology, and any increase in regulatory costs.

EXIT AND REASSEMBLY

The economic costs of an exit and reassembly scenario are considerably more difficult to quantify with even approximate accuracy. The economic costs of such a scenario would consist of three components:

(i) costs of temporary unemployment or underemployment of scientific, professional, and others with skills specialized to the nuclear industry during the period of dislocation as the industry winds down;

(ii) the risk that reassembly might prove impracticable because of the inability to reassemble skilled personnel and specialized capital;

(iii) higher capital costs for the first round of orders following reassembly.

Quantification of these three types of costs is extremely difficult. The costs of unemployment/underemployment, for example, may be significantly large, and are generally cited as the main reason for short-term measures, such as concessional financing of reactor exports.

With respect to the impact on capital costs, should the reassembly option be followed successfully, one Ontario Hydro estimate put the increase for stations built subsequent to reassembly at about 20 per cent of the estimated cost of the first four-unit station, with no penalty attached to subsequent stations. This would amount to approximately $1.5 billion in $1995 for a Darlington-sized station, or $0.5 billion in $1981. However, the utility also recognized that there are several specialized areas where reassembly might be very difficult particularly with respect to highly qualified personnel. With its large nuclear program, Ontario Hydro obviously has a strong interest in the availability of an industrial CANDU capability.

Industrial and Technological Benefits

The previous subsection concentrated on those aspects of doing without CANDU which are the most easily measured – i.e. those which can be directly interpreted in terms of costs to the Canadian economy. This subsection addresses an equally important but somewhat less tangible topic – the contribution of CANDU in terms of overall industrial, technological and trade benefits. These are key considerations because CANDU offers advantages which go well beyond its role as a cheap and reliable source of electricity. Perhaps most importantly, it represents an indigenous energy source based on Canadian technology and Canadian resources.

In addition, because the design and the content of the CANDU is Canadian, it offers industrial benefits that an imported reactor could not match. It provides desirable highly skilled employment. It represents a stimulus to a wide range of research, development, and other high-technology activities in Canada: instrumentation, quality assurance, design engineering, and so on. If imported reactors were used in Canada, these activities would be carried out in the vendor countries' laboratories and workshops.

Export of CANDU reactors can also be seen as a component of Canada's overall trade strategy. Despite difficulties encountered in marketing CANDU abroad, it constitutes a symbol of Canada's excellence in high technology. The effect of CANDU exports can ''spill over'' and influence the success of other Canadian high technology exporting efforts.

If Canada were to import LWRs from another country, many of these industrial and trade benefits would be lost, along with a certain degree of energy security. Of course, not all the 30 000 jobs in Canada's nuclear industry would disappear. Many of the construction and installation jobs would remain, and some components would surely be manufactured here. As long as the buyers' market for nuclear reactors continues, Canada would be able to negotiate some industrial benefits: some fraction of the costs could be guaranteed to be spent in Canada; technology transfer could be arranged; branch plants could be set up for some components, some of which might even obtain world product mandates.

If Canada were to abandon the CANDU option and simply rely on coal (mainly imported) in those areas where CANDU is economically attractive, or allow the industry to run down with a view to reassembly at a later date, many industrial and energy security benefits would be lost. Highly skilled labour specialized to the nuclear industry would be diverted to other uses. Capital specialized to the nuclear industry would be rendered idle, and Canada would become dependent on foreign sources of supply for a key energy commodity (imported coal). Both these scenarios would also imply the irretrievable loss of any export potential for CANDU.

In summary, laissez-faire policy would involve costs of adjustment imposed on the industry to meet demands in the 1990's. More generally, it would also involve foregoing the benefits an active policy would generate; profits for the industry, foreign exchange, employment, and technological spinoffs.

Summary

A policy designed to sustain the nuclear industry will require some financial support by the federal government. It is, therefore, important to keep the benefits these expenditures generate clearly in mind. With respect to domestic reactors, CANDU shows a clear economic advantage over coal and over imported LWRs. The benefits of sustaining the option, as opposed to an exit/reassembly scenario, are less clear cut, but the risks involved in the latter course are high. With respect to industrial benefits, technological development and trade, sustaining CANDU appears superior to all three laissez-faire alternatives. Support for export sales will generate industrial development, trade, and technological spinoff benefits.

12. PROSPECTS FOR THE CANADIAN NUCLEAR INDUSTRY: SUMMARY AND CONCLUSIONS

From 1964 to 1978, the Canadian nuclear industry sold 24 reactor units (including research and power reactors), an order rate of almost 2 units per year. In contrast, since 1978 there have been no firm orders.* The industry is therefore facing an indeterminate period of excess capacity, its future clouded by uncertainty regarding the timing and magnitude of the next round of orders. The outlook for the industry depends upon its domestic and export sales prospects.

Domestic Market

Most provincial utilities currently have excess capacity and will require few additions to capacity, beyond those currently under construction, for a decade or more. However, most forecasts indicate that new generating capacity will be required in the 1990's. Nuclear energy is an economically attractive option for meeting part of this load growth. Because of long lead times, orders will need to be placed in the 1980's for capacity additions required in the 1990's. The big uncertainties are the number and timing of future nuclear orders, in relation to the nuclear industry's capacity.

The market for CANDU in Canada this century will likely be confined to Ontario, the Maritimes and possibly Québec. Depending on the coal/nuclear mix chosen by the province and the rate of electrical demand growth ultimately realized, Ontario could choose to build no new reactors beyond Darlington, relying entirely on coal, or decide to meet load growth exclusively with nuclear energy and require as many as six post-Darlington reactors to 2000.

The Maritimes are also a potential market with a second Lepreau reactor a good possibility sometime in the 1980's. Two additional units by the end of the century are also possible although less probable than Lepreau 2.

In Québec the outlook is more uncertain. With load growth rates falling in Québec the province could rely on its hydro capacity to supply all of its needs for the rest of the century. However there appear to be lucrative prospects for sales of electricity to Québec's U.S. neighbours, and economic activity could pick up resulting in increased domestic demand rates. In any case, there is a high probability that Québec will require sizable nuclear commitments early in the next century. It may well choose to ease back into a nuclear program by committing perhaps two units to be in-service in the late 1990's.

Prospects for nuclear sales in Western Canada this century are low, though there is a chance for one unit to come in-service very near the end of the century, possibly in conjunction with the tar sands.

The range of uncertainty is, therefore, large. It is arithmetically possible that as many as 12 reactor units may be required to meet domestic load growth this century. More realistically, up to 7 reactor units will likely be required, coming on stream in the 1990's. If the upper end of this range were realized, it should be possible to sustain a rationalized industry.

What is certain, however, is that the situation over the next few years will be critical for the industry. Given excess capacity being experienced by domestic utilities, domestic orders in the early to mid-1980's will likely be non-existent on the basis of the domestic market alone. Virtually all firms in the industry could be out of business by the mid-to-late 1980's, thereby foreclosing the capability of the industry to meet the next round of orders in the late 1980's.

Under these circumstances, the export market over the next few years becomes extremely important because it offers the best prospect of a nearer term sale which would reduce somewhat the industry's short term problems of excess capacity.

*Romania has contracted for two units, one in 1979 and one in 1981, but up to the time of writing had not firmly placed any equipment orders.

The Export Market

Export markets will be soft for at least the next decade and perhaps to the end of the century. Competition is strong and other producers are also motivated by excess capacity in their domestic markets to pursue export prospects.

Despite these difficulties, an export market does exist and CANDU possesses features which will continue to make it attractive to many countries. Romania has recently agreed to a two-unit sale. Romania, Korea, Mexico and perhaps Yugoslavia are the best near-term prospects, with other opportunities concentrated in the latter part of the 1980's.

While the export sector will not likely sustain the nuclear industry in the long run, one or more additional near-term sales will be critical to maintaining the industry into the mid 1980's, at which time the outlook for domestic sales in the 1990's should be much clearer.

The Policy Question

Given the outlook in both domestic and export markets, a fundamental question posed is whether the nuclear industry in Canada will survive the 1980's to serve a probable domestic demand for nuclear energy in the 1990's; and what, if anything, the government should do to sustain the industry. To answer this question, the review has briefly examined the consequences of allowing the industry to disband over the next few years.

In this case, to meet load growth in the 1990s, Canada could (i) do without nuclear power; (ii) import light water technology from abroad; or (iii) reassemble the industry. All these options involve significant costs and risks.

The first forgoes the economic and industrial benefits of maintaining a generating technology which is already considerably less expensive than coal. The second involves the loss of the industrial spinoffs, high technology employment, and the energy security benefits of an independent CANDU option. The third imposes the economic costs of reassembling the industry along with the risk that such an alternative may ultimately not be feasible in technical and economic terms.

While more quantitative analysis of these options now needs to be undertaken, it appears sensible at this point to pursue policy options which will maintain the nuclear option for the next few years, at which time new orders for reactors to come on stream in the 1990's should begin to be placed. However, it is also possible that the domestic and export outlook will not improve, and the same problem will once again have to be faced in several years.

Policy Options

Export Markets

The export market appears to offer good prospects for additional near term sales. Policy options with respect to export sales are therefore particularly important. At the simplest level, AECL could be allowed more commercial freedom to pursue export sales. This process has already begun. Much will depend on the ability of AECL to work together with government, industry and the utilities to put forward a coherent export marketing effort. The submission of a comprehensive bid to Mexico early in 1982 is evidence that this process is well underway.

More difficult and sensitive options would be changes in Canada's safeguards policy. While such changes might improve sales prospects in a few cases, they are high risk options in political and public acceptability terms. A Cabinet review of safeguards policy in parallel with this one has concluded that Canada should maintain its safeguards policies, while implementing them in a pragmatic way which

takes into account the energy needs of our nuclear partners. Agreements recently reached with a number of nuclear partners indicate that Canada's strict safeguards are not a significant barrier to new export possibilities.

Finally, it is clear that concessional financing may be a necessary condition to meet competition in the export market at least over the next few years. Government commitment in terms of Ministerial visits and support is of value in itself, but will ultimately have to find expression in financial terms.

Domestic Options

While scope for policy initiatives in the domestic market is limited, some positive steps are possible. The most promising option in the short term is federal support for a second CANDU reactor at Point Lepreau in New Brunswick, dedicated partially for electricity export. Beyond this, the most promising possibilities are federal initiatives aimed at achieving further nuclear commitments in Québec and discussions with Ontario about the possibility of committing new reactors, at least partially for electricity export. Initiatives which would be attractive to other provinces should also be explored.

APPENDIX 1

PROPOSED ADDITIONS TO GENERATING CAPACITY

Province & Station		Type*	Year	Additions Proposed (MWe)
Newfoundland	Hind's Lake	H	1980	75
	Port aux Basques	GT	1983	25
	Upper Salmon	H	1982	84
Nova Scotia	Lingan	SC	1980	150
	Annapolis Royal	H	1983	20
	Gisborne Canal	H	1980	3.5
New Brunswick	Dalhousie	SOC	1979	200
	Mactaquac	H	1980	200
	Point Lepreau	N	1981	680
Québec	Delaney	H	1988	4 X 255
			1989	4 X 255
			1990	2 X 255
	Gentilly 2	N	1983	685
	Iles-de-la-Madeleine	IC	1983	6
	La Grande – LG-1	H	1988	5 X 114
			1989	3 X 114
			1990	2 X 114
	LG-2	H	1980	4 X 333
			1981	6 X 333
			1982	2 X 333
	LG-3	H	1982	3 X 192
			1983	8 X 192
			1984	1 X 192
	LG-4	H	1984	7 X 293
			1985	2 X 293
	Manic 5	H	1985	4 X 247
Ontario	Atikokan	SC	1984	200
			1987	200
Ontario	Bruce B	N	1982	800
			1983	800
			1985	800
			1986	800
	Darlington	N	1988	900
			1989	900
			1990	900
			1991	900
	Pickering B	N	1982	2 X 540
			1983	2 X 540
	St. Mary's	H	1982	3 X 18
	Thunder Bay	SC	1981	2 X 150
Manitoba	Limestone	H	1989	3 X 117
			1990	4 X 117
			1991	3 X 117
	Long Spruce	H		

Province & Station		Type*	Year	Additions Proposed (MWe)
Saskatchewan	Poplar River	SC	1980	300
			1982	300
Alberta	Battle River	SC	1981	375
	Keephills	SC	1983	400
			1984	400
	Sheerness	SC	1985	375
			1986	375
	Sundance	SC	1980	375
	Medicine Hat	GT		
British Columbia	Gordon M. Shrum	H	1980	300
	Peace Canyon	H	1980	4 X 175
	Revelstoke	H	1983	3 X 450
			1984	450
	Seven Mile	H	1980	2 X 202.5
Northwest Territories	Various Communities	IC	1980	1.28

* Legend

Hydro	H
Steam (Coal)	SC
Steam (Gas)	SG
Steam (Oil)	SO
Nuclear	N
Internal Combustion	IC
Gas Turbine	GT

APPENDIX 2

DETAILED SAFEGUARDS REQUIREMENTS

The NSG guidelines require adherence to the following principles.

(1) ''trigger list'' items (nuclear materials, certain other special materials such as heavy water and reactor-grade graphite, and equipment which is considered to be of particular importance in the nuclear fuel cycle from a nonproliferation perspective) should be exported only upon formal assurances explicitly excluding uses which would result in any nuclear explosion;

(2) ''trigger list'' nuclear materials should be placed under effective physical protection;

(3) ''trigger list'' items should be exported only when covered by IAEA safeguards;

(4) the export of reprocessing, enrichment, or heavy water production technology or of facilities based on that technology should require the application of IAEA safeguards to any facility employing or drawing upon that technology;

(5) IAEA safeguards apply to any facilities of the same type constructed during an agreed-upon period in the recipient country (the so-called deeming provision);

(6) restraint should be exercised in the export of sensitive facilities and technology (reprocessing and enrichment) and of weapons-usable materials;

(7) assurances covering the possible future re-transfer of ''trigger lists'' items should be required by the original suppliers of those items. This provision also covers the technologies listed under item 4;

(8) 'best endeavours' should be exercised in achieving prior consent for reprocessing. The guidelines stress the importance of agreement between supplier and recipient on arrangements for reprocessing, storage, alteration, use, etc., of weapons-useable material arising from supplied nuclear material or facilities.

The 1974 Policy Statement

In December of 1974, primarily as a response to the Indian nuclear explosion earlier that year, the Canadian government announced an upgrading of its safeguards policy. Agreements concluded under the new policy have all included:

(1) a binding assurance that Canadian-supplied items would be used exclusively for peaceful, non-explosive purposes;

(2) a binding assurance that Canadian-origin items would be covered by international (IAEA) safeguards for their lifetime.

(3) a binding assurance that any nuclear material produced by or with Canadian-supplied items would be subject to conditions (1) and (2);

(4) a binding recognition of Canada's right of prior consent over the re-transfer beyond the recipient's jurisdiction of any Canadian-origin items or of any nuclear material used with or produced by those items;

(5) a binding recognition of Canada's right of prior consent over the reprocessing of Canadian-origin nuclear material or of nuclear material irradiated in a Canadian-origin facility as well as over the subsequent storage of any plutonium produced;

(6) a binding recognition of Canada's right of prior consent over the enrichment beyond 20 per cent and the subsequent storage of Canadian-origin uranium;

(7) a binding recognition of Canada's right to apply fall-back safeguards should IAEA safeguards cease to be applied for any reason; and

(8) a binding commitment that adequate physical protection measures would be applied.

The 1976 Policy

In December 1976, the government announced that new nuclear agreements would be authorized only for those non-nuclear weapons states which had either signed the NPT and thereby accepted IAEA safeguards on all their nuclear activities, current and future, or made an equally binding commitment to non-proliferation and accepted NPT type full-scope safeguards.

APPENDIX 3

THE CANDU NUCLEAR POWER SYSTEM

This appendix provides a highly simplified description of the CANDU nuclear reactor system. The acronym CANDU comes from CANada-Deuterium-Uranium.

In simplest terms, a reactor system is a way of transforming the fission energy of uranium into useful heat just as a coal-fired generating station is a system for transforming the chemical energy stored in coal into useable heat (see Figure A3-1).

The reactor system which has evolved in Canada is unique in many respects. It is cooled and moderated by heavy water (or deuterium oxide) and fuelled by natural uranium.

In a conventional nuclear reactor of the CANDU or light water reactor (LWR) type, it is necessary to slow or moderate the speed of the neutrons given off during the fission process. However all moderator materials absorb some neutrons and, because natural uranium contains only 0.7 per cent of the fissionable isotope uranium-235, it is difficult to maintain a continuous chain reaction. There are two possible basic solutions to this problem:

- the concentration of U-235 can be increased by enriching the fuel, as in the LWR design;
- a moderator such as heavy water, which absorbs very few neutrons, can be employed, as in the CANDU design.

In a CANDU reactor, pressurized heavy water coolant, in a circuit separate from the moderator, is pumped over the fuel bundles removing the heat released in the fission reaction. This heat is then transported to heat exchangers and boilers and is used to produce steam which turns the turbine-generator to produce electricity.

The design details are shown in a more detailed, but still simplified schematic in Figure A3-2.

The other key features which distinguish the CANDU system from other reactor systems are:

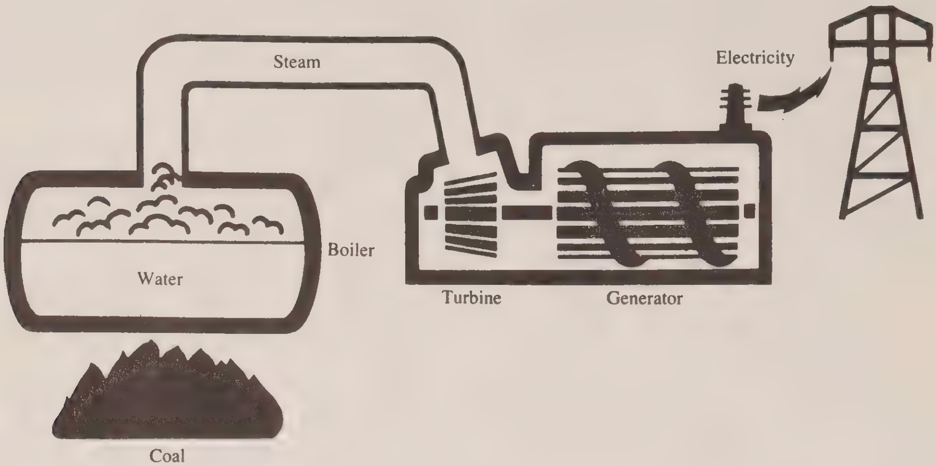
- some of CANDU's design features such as the separate, cool moderator, give it some inherent safety advantages;
- the use of a pressure tube design rather than the single large pressure vessel design as in the LWR makes the CANDU system more suitable for countries with less developed industrial structures;
- the use of heavy water and the pressure tube design maximizes the efficiency of uranium use;
- the pressure tube and fuel bundle design facilitates refuelling the reactor without shutting it down;
- the system is easily adaptable to more advanced fuel cycles (reprocessed uranium, thorium).

As Figures A3-1 and A3-2 show, many parts of a nuclear station are similar to other types of thermal generating stations – for example, the turbine systems and other civil works. The components which are unique to a nuclear station, the reactor assembly, fuelling system, heat transport system, moderator system, control systems and safety systems, are located within the containment building and referred to as the Nuclear Steam Supply System (NSSS). The manufacturers of components and suppliers of engineering services (as well as heavy water) specific to the NSSS are the focus in this paper. A schematic representation of the NSSS is given in Figure A3-3.

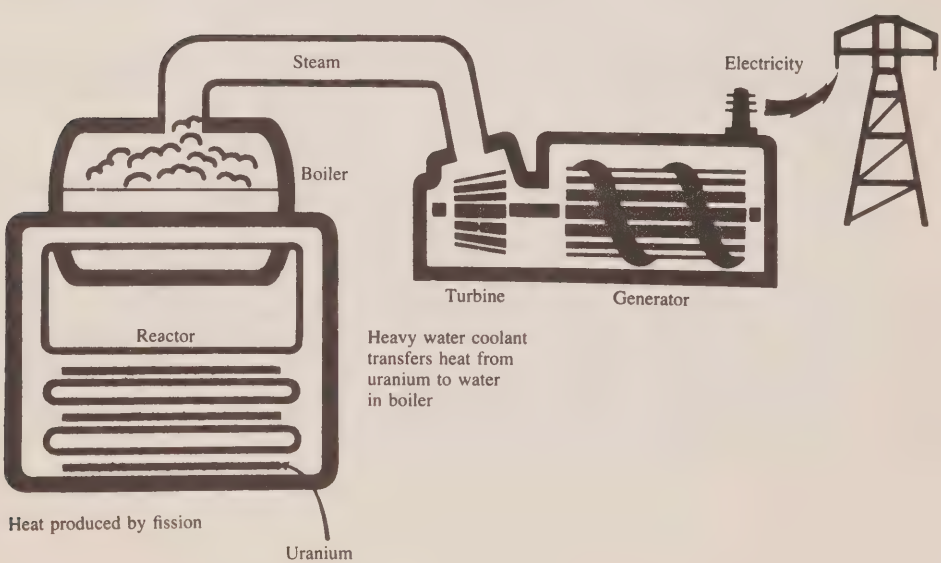
FIGURE A3-1

OPERATION OF FOSSIL-FUELLED AND CANDU POWER PLANTS

Fossil-Fuelled



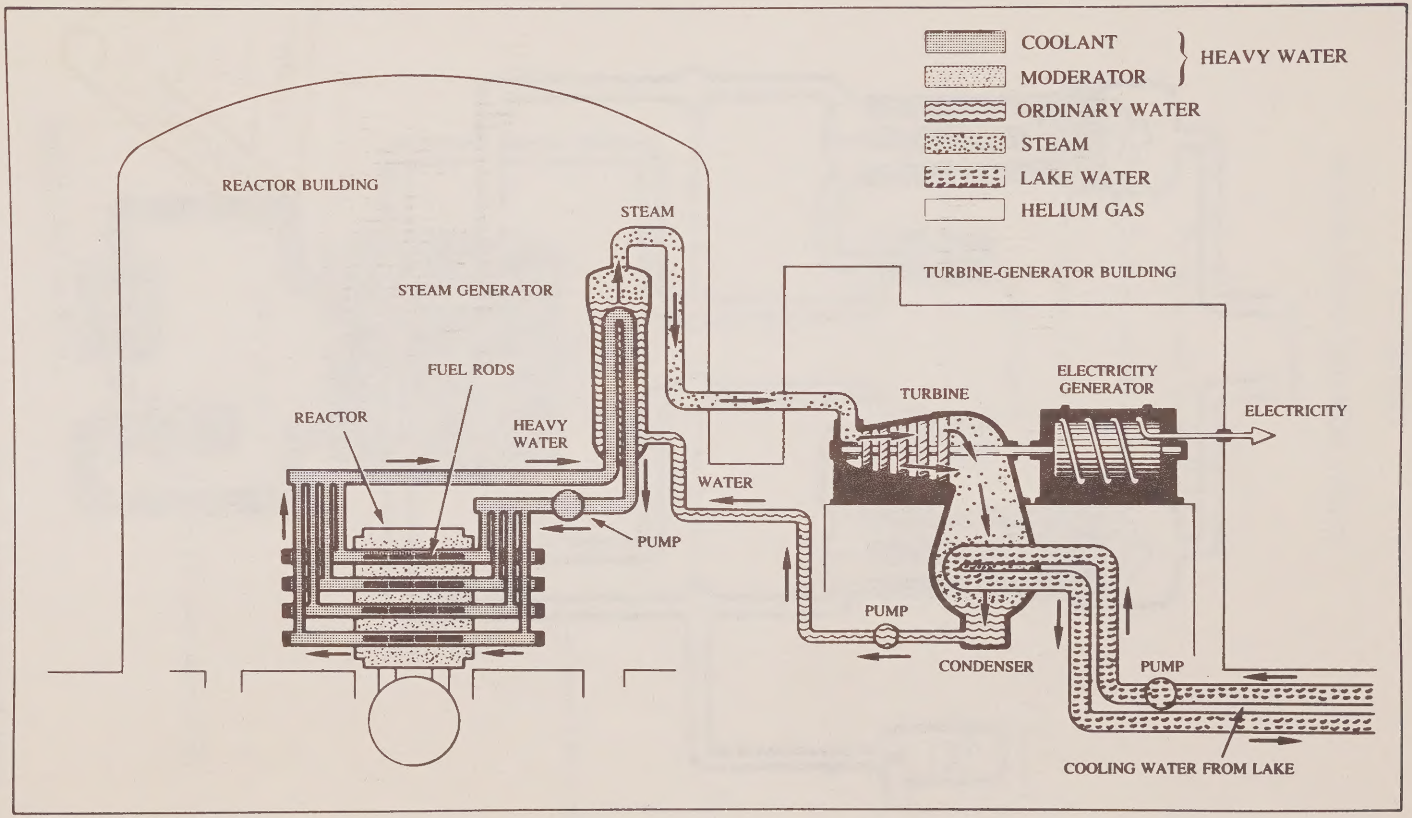
CANDU



Source: Atomic Energy of Canada Limited

FIGURE A3-2

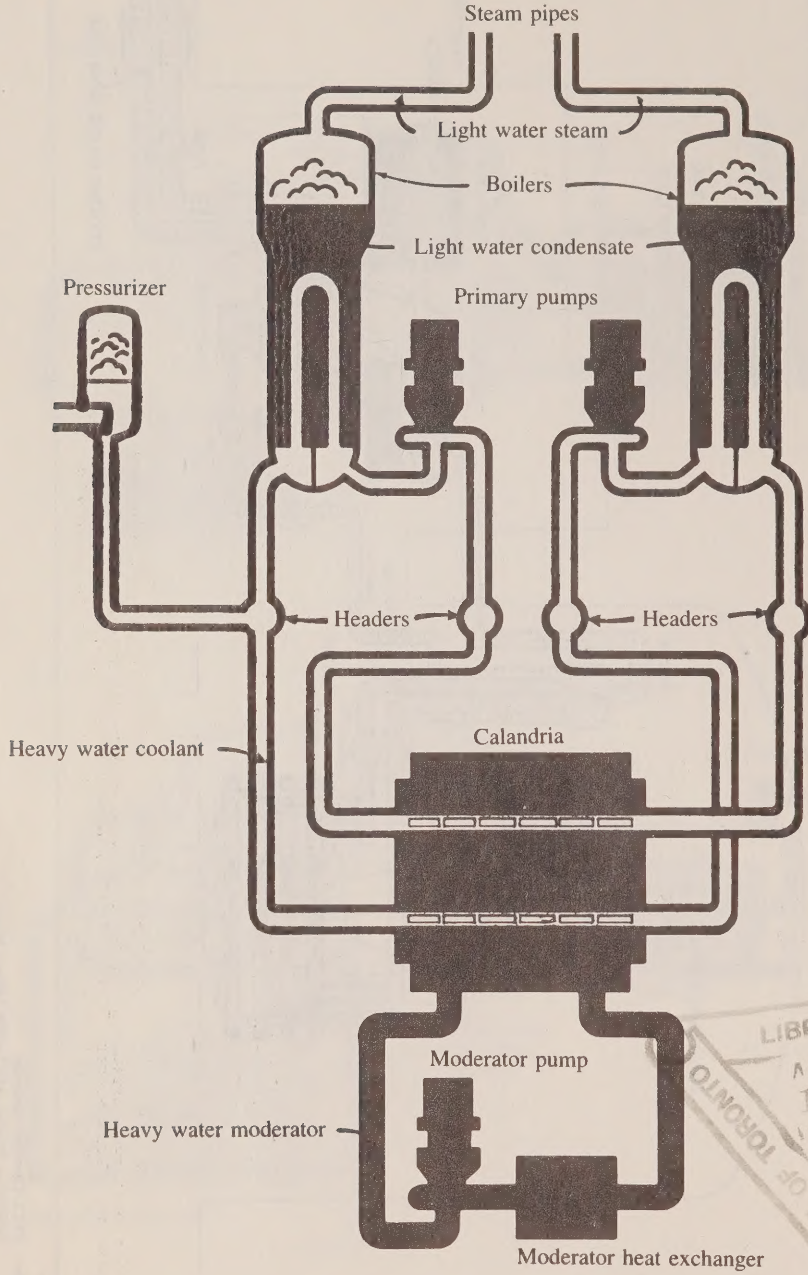
THE CANDU NUCLEAR GENERATION STATION



Source: AECL-Chemical Company
Publication Number AECL-4609, "Heavy Water"
August 1979

FIGURE A3-3

CANDU REACTOR FLOW DIAGRAM



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Source: Atomic Energy of Canada Limited